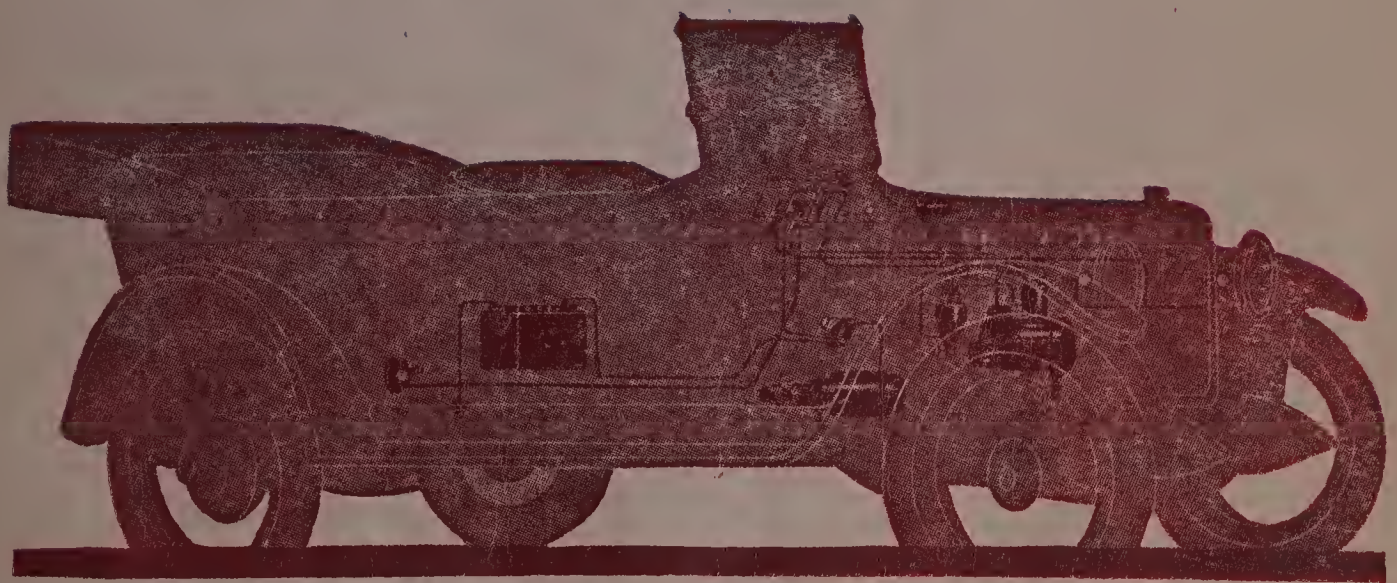


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MODERN ELECTRICAL MOTOR CAR EQUIPMENT

ITS PRODUCTION, OPERATION, MAINTENANCE AND REPAIR



Do you realize that on the Automobile there is a complete Electrical Power Plant. The most nearly self-operating, self-sustaining feature of

THE MODERN MOTOR CAR

By Thomas E. Countryman, President

SATISFACTION GARAGE

Kansas City, Missouri

Modern Electrical
MOTOR CAR
Equipment

Its Production, Operation, Maintenance
and Repair



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Study Carefully

	POSITIVE TERMINAL OF BATTERY OR GENERATOR SOMETIMES ABBREVIATED "P"			GROUND TO ENGINE OR FRAME	
	NEGATIVE TERMINAL OF BATTERY OR GENERATOR SOMETIMES ABBREVIATED "N"				
	CARBON OF DRY BATTERY		ZINC OF DRY BATTERY		
	BATTERY-STORAGE OR DRY CELL		CELLS IN SERIES		
	MOTOR-GENERATOR 3-TERMINAL		MOTOR-GENERATOR 4-TERMINAL		
	AMMETER		VOLTMETER		PRIMARY
	SECONDARY		GENERATOR		MOTOR
	WIRES JOINED TOGETHER, SAME CIRCUIT				
	WIRES CROSSING, SEPERATE CIRCUITS				
	RHEOSTAT OR VARIABLE RESISTANCE			INCANDESCENT LAMP	
	METHOD OF SHOWING AN INDUCTIVE COIL				
	METHOD OF SHOWING A NON-INDUCTIVE COIL (ALSO USED TO SHOW INDUCTIVE COIL WHEN THERE IS NO DANGER OF CONFUSION)				
	USED FOR RESISTANCE ONLY			AUTOMATIC CUT-OUT	
	SHUNT WOUND MACHINE MOTOR OR GENERATOR			SERIES WOUND MACHINE MOTOR OR GENERATOR	
	ARMATURE AND BRUSHES OF MOTOR AND GENERATOR				
	MOTOR BRUSH SWITCH		SWITCH		CONTACT POINTS
	PUSH BUTTON OR LIGHTING SWITCH			STARTING SWITCH	
	PUSH BUTTON		FUSE		BALLAST COIL
	COWL LIGHT			CONDENSER	
	PRIMARY COARSE WIRE		SECONDARY FINE WIRE		BOTH IGNITION COIL
	HEAVY CABLE		ARROW INDICATES DIRECTION OF CURRENT FLOW		
	CLOCKWISE REVOLUTION		COUNTER-CLOCKWISE REVOLUTION		
	VOLT, UNIT OF POTENTIAL OR PRESSURE			AMPERE, UNIT OF CURRENT QUANTITY	
D.C	DIRECT CURRENT, FLOWS CONTINUOUSLY AND ALWAYS IN ONE DIRECTION				
A.C	ALTERNATING CURRENT, FLOWS FIRST IN ONE DIRECTION THEN THE OTHER				
K.W.	KILOWATT, (1,000 WATTS)		HORSE POWER (746 WATTS)		
W	WATT= ONE VOLT X ONE AMPERE				
P.D.	Potential or Pressure of a Current				
EMF	Electro Motive Force				

ELECTRICAL SYMBOLS

MODERN ELECTRICAL MOTOR CAR EQUIPMENT

CHAPTER 1. ELECTRICITY.

What is Electricity? A great many people have strange ideas of electricity, and imagine that a person must be out of the ordinary who can harness up electricity and make it do work. Now if you are figuring on analyzing and finding out why electricity does certain things, you are on the wrong track. Electricity is the name of a natural force that exists everywhere; it is in your body; it is in your clothes; in fact, it is everywhere, and the only reason you do not feel a shock is because the electricity is not in motion. This electricity that exists everywhere is in the form of magnetism, and is at rest and is not noticeable.

By a great deal of experimenting with electricity men have been able to find out how to set it in motion, and harness it up, and utilize it to a great advantage, and it has played a very important part in modernizing the automobile.

CHAPTER 2. MAGNETISM.

General Properties of Magnets.—It has been known for many centuries that certain kinds of ore known as magnetite have the property of attracting small bits of iron and steel. This ore probably received its name from the fact that it is especially abundant in the Province of Magnesia in Thessaly, although the Latin writer Pliny says that the word *Magnet* is derived from the name of the Greek Shepherd Magnes who, on the top of Mount Ida observed the attraction of a large stone from his iron crook. Pieces of this ore which exhibit this attractive property are known as “natural magnets.” It was also known to the ancients that artificial magnets may be made by stroking pieces of steel with natural magnets, but it was not until about the twelfth century that the discovery was made that a suspended magnet will assume a north and south position. Because of the latter property natural magnets became known as “load-stones,” or “leading stones,” and magnets, either artificial or natural, began to be used for determining direction.

The first mention of the use of the compass in Europe is in 1190; it is thought to have been introduced from China. Magnets are now made by either stroking bars of steel in one direction with a magnet, or by passing electric currents about the bar in a manner to be described later. The form shown in Diagram 1 is called a “bar magnet.” That shown in Diagram 2 is a horseshoe magnet. The horseshoe magnet form is the more common. If a magnet is dipped into iron filings, the filings will be seen to cling in a tuft near the end, but scarcely at all near the middle, as shown in Diagram 3.



Diag.1 A bar magnet



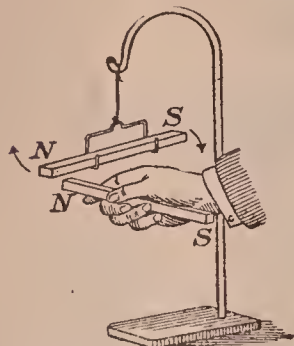
Diag.2 A horseshoe magnet



Diag.3 Iron filings clinging to bar magnet

These places near the end of a magnet, at which its strength seems to be concentrated, are called the “poles of the magnet.” The end of a freely swinging magnet which points to the north is designated as the north seeking, or simply the north pole (N), and the other end as the south seeking or the “south pole” (S). The direction in which a compass needle points is called the “magnetic meridian.”

The Law of Magnetic Attraction and Repulsion.—In the experiment with the iron filings no particular difference was observed between the action of the two poles. That



Diag. 4 Magnetic attractions and repulsions

there is a difference, however, may be shown by experimenting with two magnets, either of which may be suspended as shown in Diagram 4. If two north poles are brought near one another they are found to repel each other. The south poles likewise, are found to repel each other, but the north pole of one magnet is found to be attracted by the south pole of another. The results of these experiments may be summarized in a general law. **MAGNETIC POLES OF LIKE KIND REPEL EACH OTHER, WHILE POLES OF UNLIKE KIND ATTRACT EACH OTHER.**

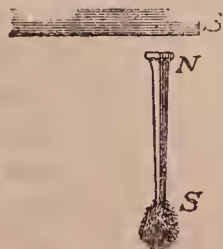
The force which any two poles exert upon each other has been found, like the force of gravitation, to vary inversely as the square of the distance between them. A unit pole is defined as a "pole" when placed at a distance of one centimeter from an exactly similar pole will repel it with a force of a dyne, which, acting upon a gram per second, generates a velocity of one centimeter.

Magnetic Materials.—Iron and steel are the only substances which exhibit magnetic properties to any marked degree. Nickel and cobalt are also attracted appreciably by strong magnets. Bismuth and antimony substance are actually repelled instead of attracted, but the effects are very small. Recently it has been found possible to make quite strongly magnetic alloys out of certain nonmagnetic materials. For example, a mixture of 65% copper, 27% manganese, and 8% aluminum is quite strongly magnetic. These are called "hesular alloy." For practical purposes, however, iron and steel may be considered as the only magnetic materials.

Magnetic Induction.—If a small unmagnetized nail is suspended from one end of a bar magnet, it is found that a second nail may be suspended from this first nail which, itself, acts like a magnet. A third from the second, etc., and so on, as shown in Diagram 5; but if the bar magnet is carefully pulled away from the first nail, the others will instantly fall away from each other, thus showing that the nails were strong magnets only so long as they were in contact with the bar magnet. Any piece of soft iron may be thus magnetized temporarily by holding it in contact with a permanent magnet; indeed, it is not necessary that there be actual contact, for if a nail is simply brought near the permanent magnet, it is found to become a magnet. This may be proved by presenting some iron



Diag. 5 Magnetism induced by contact



Diag. 6 Magnetism induced without contact

filings to one end of a nail, held near a magnet in the manner shown in Diagram 6. Even inserting a plate of glass, or of copper, or any other material except iron between the north and south will not change appreciably the number of filings which cling to the end of the south pole of the nail. This shows the fact that nonmagnetic materials are transparent to magnetic forces, but as soon as the permanent magnet is removed, most of the filings will fall. Magnetism produced in this way, by the mere presence of adjacent magnets, with or without contact, is called induced magnetism. If the induced magnetism of the nail in Diagram 6 is tested with a compass needle it is found that the remote or the farthest away pole of the nail is of the same kind

as the inducing pole, while the near pole is of unlike kind. This is the general law of magnetic induction.

Magnetic induction explains the fact that a magnet attracts an unmagnetized piece of iron, for it first magnetizes it by induction, so that the near pole is unlike the inducing

pole, and the remote pole like the inducing pole, and then since two unlike poles are closer together than the like poles, the attraction overbalances the repulsion, and the iron is drawn towards the magnet. Magnetic induction also explains the formation of the tufts of iron filings shown in Diagram 3. Each little filing becomes a temporary magnet, such that the end which points towards the inducing pole is unlike this pole, and the end which points away from it is like this pole. The brushlike appearance is due to the repulsive action which the outside free poles exert upon each other.

Retentive and Permeability.—A piece of soft iron will very easily become a strong temporary magnet, but when removed from the influence of the magnet, it loses practically all of its magnetism. On the other hand, a piece of steel will not be so strongly magnetized as soft iron, but it will retain a much larger fraction of its magnetism after it is removed from the influence of the permanent field. This power of resisting either magnetization or demagnetization is called "retentivity." Thus steel has a much greater retentivity than wrought iron, and in general, the harder the steel the greater its retentivity. A substance which has the property of becoming strongly magnetic under the influence of a permanent magnet, whether it has a high retentivity or not, is said to possess permanent ability in large degrees; thus iron is much more permeable than nickel.

Magnetic Lines of Force.—If we could separate the north and south poles of a small magnet so as to get an independent north pole, and were to place this north pole near the north pole of a bar magnet it would move over to the south pole along some curved



Diag. # 7 A line of force set up by the Magnet A B



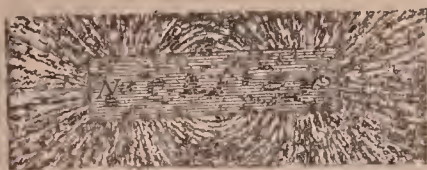
Diag. 8 Showing direction of a motion of an isolated pole near a magnet

path similar to that shown in Diagram 7. The reason it would move in a curved path is that it would be simultaneously compelled by the north pole on the bar magnet, and attracted by its south pole, and the relative strength of these two forces would continually change, as the relative distance of the moving poles from these two poles change. To verify this conclusion let a strongly magnetized sewing needle be floated in a small cork in a shallow dish of water, and let a bar or horseshoe magnet be placed just above or just beneath the dish, as shown in Diagram 8. The cork and needle will then move as would an independent pole, since the remote pole of the needle is so much farther from the magnet than the near pole its influence of the motion is very small. The cork will actually be found to move in a curved path from north to south. Any path which an inde-

pendent north pole would take in going from north to south is called a line of force. The simplest way of finding the direction of this path at any point near a magnet is to hold a short compass needle at the point considered. The compass needle sets itself along the lines in which its pole would move if independent, that is, along the lines of force which pass through the given point, as illustrated in Diagram 7.

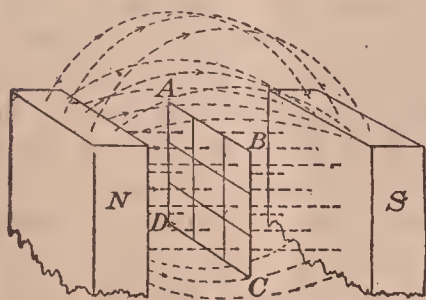
Fields of Force.—The region about a magnet in which its magnetic force can be detected is called its field of force. The easiest way of gaining an idea of the way in which the lines of force are arranged in the magnetic field about any magnet is to sift iron filings upon a piece of paper placed immediately over the magnet. Each little filing becomes a temporary magnet by induction, and therefore, like the compass needle, sets itself in the direction of the line of force at the point where it is.

Diagram 9 shows how the filings arrange themselves about a bar magnet; Diagram



Diag. 9 Arrangement of iron filings about a bar magnet

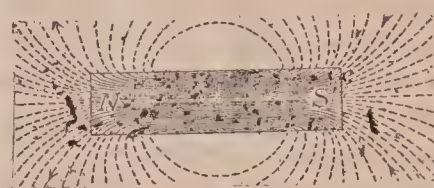
is defined as a field in which a unit magnetic pole experiences one dyne of force. It is customary to represent geographically such a field by drawing one line per square centimeter through a surface such as A, B, C, D, as shown in Diagram 11 taken at right angles to the line of force. If a unit north pole between north and south were pushed away towards south pole with a force of one thousand dynes, the strength of the field would be one thousand units, and it would be represented by one thousand lines per square centimeter.



Diag. 11 The strength of a magnetic field is represented by the number of lines of force per square centimeter

found to be a complete magnet; that is, two new poles will appear at the points of the breaking. A new north pole on the part which was the original south pole; and a new south pole on the part which was the original north pole. The subdivision may be continued indefinitely, but always the same results as indicated in Diagram 12. This suggests that the molecules of a magnetized bar may themselves be little magnets arranged in rows with their opposite poles in contact with each other. If an unmagnetized piece of hard steel is pounded vigorously while it lies between the poles of a magnet, or if it is heated to redness and then allowed to cool in this position, it will be found to have become magnetized. This suggests that the molecules of the steel are magnetized, even when the bar as a whole is not magnetized, and that magnetization may consist in causing

10 is the corresponding ideal diagram showing the lines of force emerging from the north pole and passing about in curved paths to the south pole. It is customary to imagine these lines as returning through the magnet from south to north, in the manner shown, so that each line is thought of as a closed curve. This idea was introduced by Faraday and has been found of great assistance in correlating the facts of magnetism. A magnetic field of unit strength



Diag. 10 Ideal diagram of field of a bar magnet

Molecular Nature of Magnetism.—If a small test tube full of iron filings be stroked from one end to the other with a magnet it will be found to have become itself a magnet, but it will lose its magnetism as soon as the filings are shaken up. If a magnetized knitting needle is heated red hot, it will be found to have lost its magnetism completely. Again, if such a needle is jarred or hammered or twisted, the strength of its poles as measured by their ability to pick up tacks or iron filings will be found to be greatly diminished. These facts point to the conclusion that magnetism has something to do with the arrangement of the molecules, since causes which violently disturb the molecules of a magnet weaken its magnetism. Again, if a magnetized needle is broken each part will be



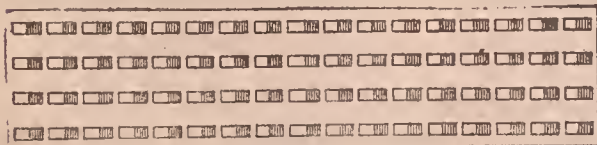
Diag. 12 Effect of breaking a magnet

them to arrange themselves in rows, end to end, just as the magnetization of the tube of iron filings mentioned above was due to a special arrangement of the filings.



Diag. 13 Arrangement of molecules in an unmagnetized iron bar

outside magnetic force into some such arrangement as that shown in Diagram 14, in which the opposite poles completely neutralize each other except in the middle of the bar. According to this view, heating and jarring weaken magnets because they tend to shake the molecules out of alignment. On the other hand, heating and jarring facilitate magnetization when the bar is between the poles of a magnet, because they assist the mag-



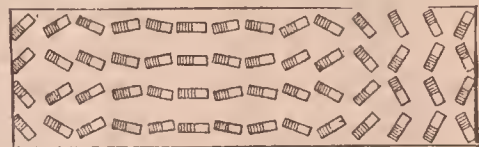
Diag. 15 Arrangement of molecules in a saturated magnet

netizing force in breaking up the molecule groups and chains, and getting the molecules into alignment. Soft iron has higher permeability than hard steel, because the molecules of the former substance are much easier to swing into alignment than those of the latter substance. Steel has a very much greater retentivity than soft iron because its molecules are not easily moved out of position once they have been aligned.

Saturation.—Strong evidence of the correctness of the above view is found in the fact that a piece of iron or steel cannot be magnetized beyond a certain limit, no matter how strong is the magnetizing force. This limit probably corresponds to the condition in which the axis of all the molecules are brought into parallelism, as in Diagram 15. The magnet is then said to be saturated, since it is as strong as it is possible to make it.

Earth Magnetism.—The fact that a compass needle always points north and south, or approximately so, indicates that the earth itself is a great magnet, having a south pole near the geographical north pole, and a north pole near the geographical south pole, for the magnetic pole of the earth which is near the geographical north pole must, of course, be unlike the pole of a suspended magnet which points towards it, and the pole of the suspended magnet which points towards the north is the one which, by convention, it has been decided to call the north pole.

Theory of Magnetism.—In an unmagnetized bar of iron or steel it is probable then that the molecules themselves are tiny magnets which are arranged either haphazard or in little closed groups or chains as in Diagram 13, so that on the whole opposite poles neutralize each other throughout the bar, but when the bar is brought near a magnet the molecules are swung around by the

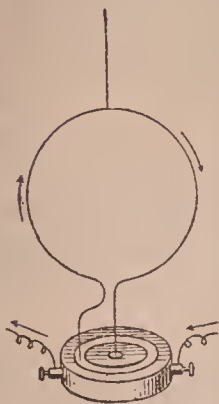


Diag. 14 Arrangement of molecules in a magnetized iron bar

netizing force in breaking up the molecule groups and chains, and getting the molecules into alignment. Soft iron has higher permeability than hard steel, because the molecules of the former substance are much easier to swing into alignment than those of the latter substance. Steel has a very much greater

CHAPTER 3. MAGNETIC PROPERTIES OF COILS

Loops of Wire Carrying a Current Equivalent to a Magnet Disc.—Let a single loop of wire be suspended from a thread in the manner shown in Diagram 16, so that its ends



Diag.16 A loop equivalent to a flat magnetic disk

dip into two mercury cups, then let the current from three or four dry cells be sent through the loops; the latter will be found to slowly set itself so that the face of the loops from which the magnetic lines emerge is towards the north. Let a bar magnet be brought near the loop, the latter will be found to behave towards the magnet in all respects as though it were a flat magnetic disc whose boundary is the wire, the face which turns towards the north being a north pole, and the other a south pole as illustrated in Diagram 17. The experiment shows what position a loop carrying a current will always tend to assume in a magnetic field, for since a magnet tends to set itself so that the lines connecting its pole are parallel to the direction of the magnetic line of the field in which it is placed, a loop must set itself so that a line connecting its magnetic pole is parallel to the lines of a magnetic field; that is, so that the plane of the loop is perpendicular to the field. (See Diagram 18), or to state the same thing in slightly different form, if a loop of wire free to turn is carrying a current in a magnetic field, the loop will set itself so as to include as many as possible of the lines of force of the field.

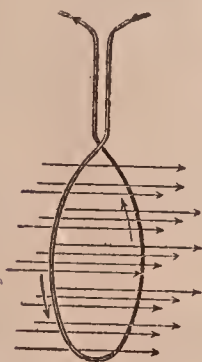
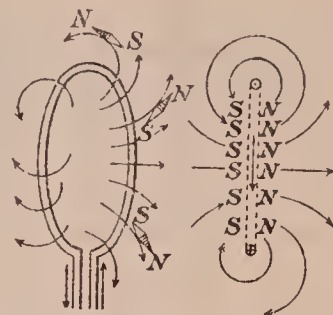


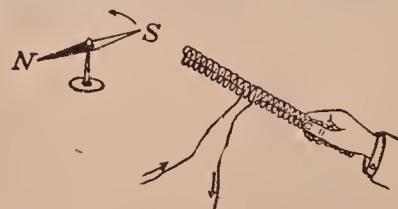
Diagram 18. Position assumed by a loop carrying a current in a magnetic field.

Helix; that is, from which end the lines of magnetic force merge, and at which end they enter it. The law is thus: if the coil is grasped in the right hand in such a way that the fingers point in the direction in which the current is flowing in the wires, the thumb will point in the direction of the north pole of the Helix as illustrated in Diagram 21. Similarly if the sign of the pole is known, but

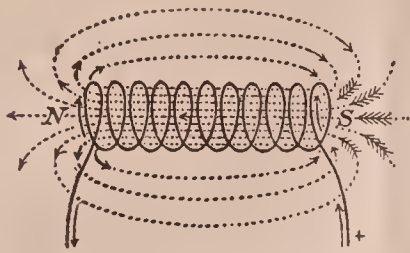


Diag.17 North pole of disk is face from which magnetic lines emerge; south face is face into which they enter

The Helix Carrying a Current Equivalent to a Bar Magnet.—Let a wire bearing a current be wound in the form of a Helix and held near a suspended magnet as in Diagram 19, it will be found to act in every respect like a magnet with a north pole at one end and a south pole at the other. This result might have been predicted from the fact that a single loop is equivalent to a flat disc magnet, for when a series of such discs is placed side by side as in the Helix the results must be the same as placing a series of disc magnets in a row; the north pole of one being directly in contact with the south pole of the next. These poles would therefore all neutralize each other excepting at the two ends. We therefore get a magnetic field of the shape shown in Diagram 20, the direction of the arrows representing as usual the direction in which a north pole tends to move. The right hand rule, as illustrated in Diagram 21 is sufficient in every case to determine which is the north and which is the south pole of a

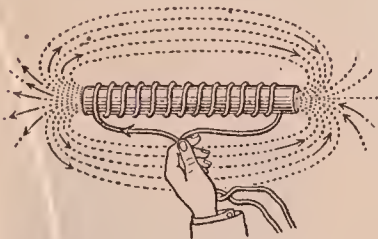


Diag.19 Magnetic effect of helix

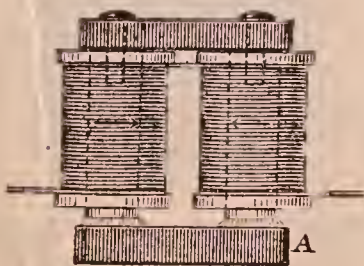


Diag.20 Magnetic field of helix

placed in the field of a permanent magnet. The new field strength about the coil is now the sum of the fields due to the core, and that due to the coil. If the current is broken the core will at once lose the greater part of its magnetism; if the current is reversed, the polarity of the core will be reversed. Such a coil with a soft iron core is called an "electromagnet." The strength of an electromagnet can be very greatly increased by giving it such form that the magnetic lines can remain in soft iron throughout their entire length



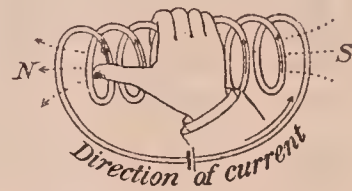
Diag.22 The bar electro-magnet



Diag.23 The horseshoe electromagnet

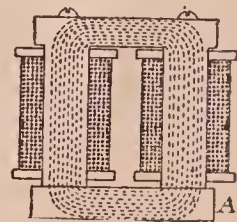
the direction of the current unknown, it may be determined as follows: if the right hand is placed against the coil with the thumb pointing towards the north pole of the Helix, the fingers will pass around the coil in the direction in which the current is flowing.

The Electromagnet.—Let a core of soft iron be inserted in the Helix as shown in Diagram 22, the poles will be found to be enormously stronger than before; this is because the core is magnetized by induction from the field of the Helix in precisely the same way in which it would be magnetized by induction, if



Diag.21 Rule for poles of helix

instead of emerging into air as they do in Diagram 22. For this reason the electromagnets are usually built in the horseshoe form and provided with an armature, A, shown in Diagram 23, through which a complete iron path for the lines of force is established as shown in Diagram 24. The strength of such a magnet depends chiefly upon the number of ampere turns which encircle it. The expression, "ampere turns," denoting the product of the number of turns of wire about the magnet by the number each turn; thus a current of one hundredth of amperes flowing in ampere flowing one thousand times around a core will make an electromagnet of precisely the same strength as a current of one ampere flowing ten times about the coil.



Diag.24 Magnetic circuit of an electro-magnet

CHAPTER 4. CURRENT PRODUCTION.

Current Production by Chemical Action.—

The simplest method of current generation is by various forms of chemical current producers which may be either primary or secondary in character. A simple form of cell is shown in section in Diagram 25, and as the action of all devices of this character is based on the same principle, it will be well to consider the methods of producing electricity by the chemical action of a fluid upon the metal. The simplest cells shown consist of a container which is filled with an electrolyte which may be either an alkali or an acid solution; immersed in the liquid are two plates of metal, one being of copper, the other zinc. A wire is attached to each plate by means of a suitable screw terminal. If the ends of the plates which are not immersed in the solution are joined together a chemical action will take place between the electrolyte and the zinc plate; in fact, any form of cell consists of dissimilar elements which are capable of conducting electricity immersed in a

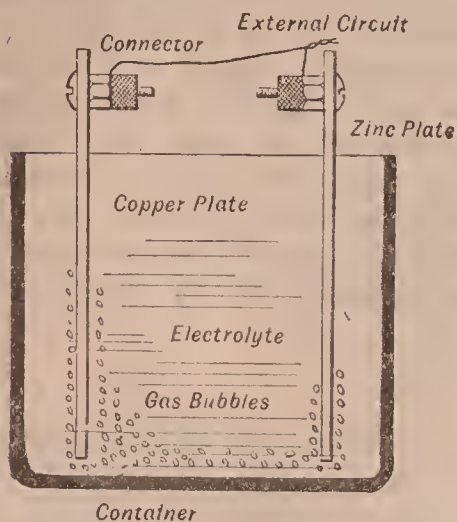


Diagram # 25 Shows principle of current production by chemical action

liquid which will act on one of them more than on the other. The chemical action of the electrolyte on the zinc liberates gas bubbles which are charged with electricity and which deposit themselves on the copper plate. The copper element serves merely as a collecting member and is termed the positive plate, while the zinc, which is acted upon by the solution, is termed the negative plate. The flow of the current is from the zinc to the copper plate through the electrolyte, and it is returned from the copper plate to the zinc element by the wires which comprise the external circuit. While in the cell shown at Diagram 25 zinc and copper are used, any other combinations of metals, between which there exists a difference in electrical conditions when one of them is acted upon by a salt or acid, may be employed. Any salt or acid solution will act as an electrolyte if it will combine chemically with one of the elements, and if it does not at the same time offer too great a resistance to the passage of the electric current. The current strength will vary with the nature of the elements used, and will have a higher value when the chemical action is greater between the negative member and the electrolyte.

As the vibration which obtains when the automobile is driven over highways makes it difficult to use cells in which there is a surplus of liquid, a form of cell has been devised in which the liquid electrolyte is replaced by a solid substance which cannot splash out of the container even if the cell is not carefully sealed. A current producer of this nature is shown in section at Diagram 26. This is known as a dry cell and consists of a zinc can in the center of which a carbon rod is placed. The electrolyte is held close to the

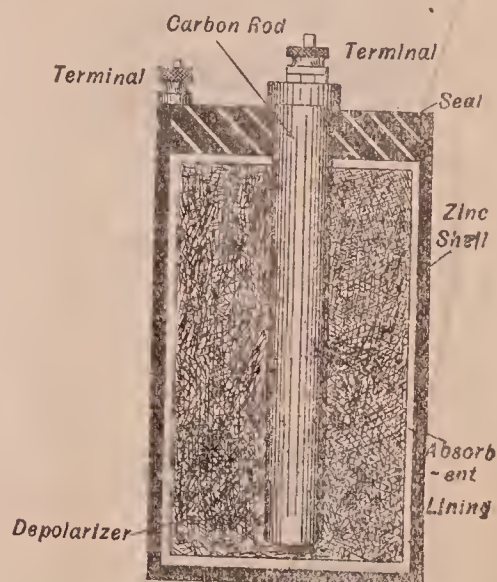
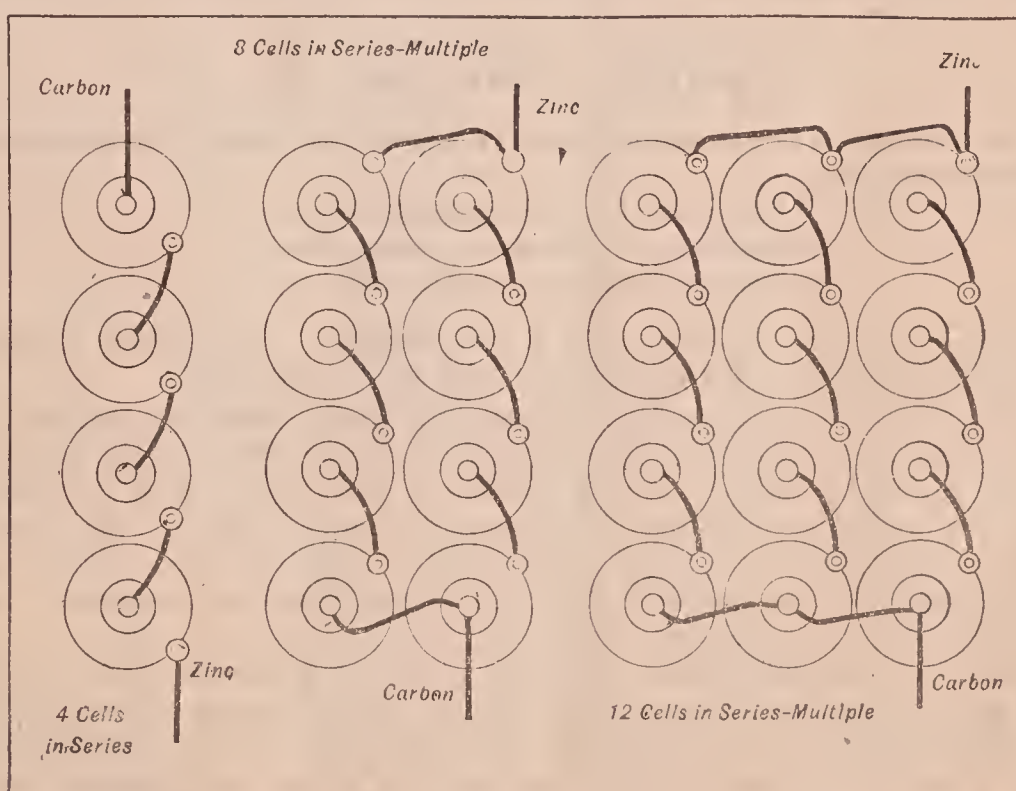


Diagram # 26 Dry Cell

zinc or negative member by an absorbent lining of blotting paper, and the carbon rod is surrounded by some depolarizing material, the top of the cell is sealed with pitch to prevent loss of the depolarizer. The depolarizer is needed that the cell may continue to generate current when the circuit of a simple cell is completed. The current generation is brisker at first than after the cell has been producing electricity for a time. While the cell has been in action the positive element becomes covered with bubbles of hydrogen gas which is a poor conductor of electricity, and tends to decrease the current output of the cell. To prevent these bubbles from interfering with current generation some means must be provided for disposing of the gas; in dry cells the hydrogen gas that causes polarization is combined with oxygen gas evolved by the depolarizing medium, and the combination of these two gases produces water which does not interfere with the action of the cell. Carbon is used in the dry cell instead of copper, because it is a cheaper material, and the electrolyte is a mixture of salammoniac and chloride of zinc which is held in intimate contact with the zinc shell which forms the negative element by the blotting paper liner. A single dry cell will not produce sufficient current when properly transformed or stepped up to ignite the charge of gas in the engine cylinders; therefore it is a common practice to combine two or more cells in such a manner that batteries are formed which will give more current than a single cell. If it is desired to increase the voltage, the cells are combined in series as shown in Diagram 27. If one dry cell



Diag. 27 Methods of Joining Dry Cells to Form Batteries of Varying Value.

will produce one and one half volts, and six volts are needed to produce the spark in the engine cylinders, the current value of one dry cell is increased by coupling three others to it in a series connection. When cells are connected in series, it is the unlike elements which are joined together. For example, the zinc of one cell should be joined with the carbon of the adjacent member by a flexible conductor; this will leave the carbon of one end cell and the zinc of the other end cell free, so that they can be joined to the apparatus in the outer circuit. When it is desired to obtain more amperage or current quantity than could be obtained from a single cell, they are joined in series multiple as

also shown in Diagram 27. With this method of wiring, two or more sets of four cells which have been joined in series are used; the zinc of one set is joined with the zinc elements of the others, and the two carbons are similarly connected. Any number of sets of cells may be connected in series multiple, and the amperage of the combination is increased proportionately to the number of sets joined together in this manner. When dry cells are connected in series, the voltage of one cell is multiplied by the number of cells, and the amperage obtained to the set is equal to that of one cell. When connected in series multiple the amperage is equal to two cells and the voltage production produced is equivalent to that obtained from four cells. When twelve cells are joined in series multiple, as shown in Diagram 27, the amperage is equal to that of one cell multiplied by three, while the voltage or current pressure is equal to that produced by one cell multiplied by the number of cells which are in series in any one set. By properly combining dry cells in this manner, batteries of any desired current strength may be obtained. The term volt and ampere are merely units by which current strength is gauged. The volt is a unit of pressure or potential which exists between the terminals of a circuit. The ampere measures current quantities or flow, and is independent of the pressure. One may have a current of high amperage at low voltage, or one having great pressure but little amperage or current strength. Voltage is necessary to overcome resistance, while the amperage available determines the heating value of the current.

CHAPTER 5. THE OHMS LAW.

One volt will force a current of electricity through one ohm of resistance at the rate of one ampere per hour.

Volts divided by ohms equals amperes.

Volts divided by amperes equal ohms.

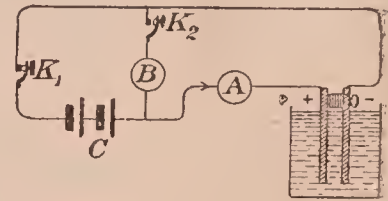
Amperes times ohms equals volts.

Example: 110 volts, 55 ohms equals two amperes. The amount passing in one hour volts times amperes equals watts, and 1000 watts a kilowatt.

As the resistance to current flow increases the voltage must increase proportionately to overcome it. A current having the strength of one ampere with the pressure of one volt is said to have a value of one watt, which is the unit by which the capacity of a generator and amount of current consumption is gauged. One of the disadvantages of primary cells, as those types which utilize zinc as a negative element, is that the chemical action produces deterioration and waste of material by oxidation. Dry cells are usually proportioned so that the electrolyte and depolarizing material become weaker as the zinc is used, and when a dry cell is exhausted it is not profitable to attempt to recharge it, because new ones can be obtained at a lower cost than the expense of renewing the worn elements. The number of dry cells necessary will vary with the system of ignition employed and the size of the motor—while two or three cells will ignite small engines such as are used in motorcycles and small stationary engines, five or six will be needed on automobile engines employing high tension ignition. When the make and break system, or low tension method is used, eight or ten cells are necessary. If the engine is a multiple cylinder one, it will draw more current than a single cylinder type, because of the greater frequency of spark. On four cylinder cars dry cells should be joined in multiple series, which is the most economical arrangement. Cells used in multiple connections are more enduring than if the same number were used independently in single series connection. A disadvantage of a dry cell battery is that it is suited only for intermittent service and it will soon become exhausted if used where the current demands are severe; for this reason most automobiles in which batteries are used for ignition, employ storage or secondary batteries to furnish current regularly, and a set of dry cells is provided for use only in case of emergency when the storage battery becomes exhausted.

CHAPTER 6. STORAGE BATTERIES.

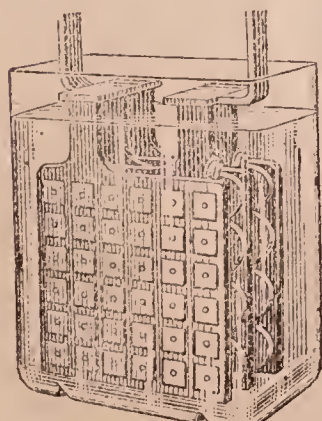
Let two six by eight inch lead plates be screwed to a half inch strip of some insulating material as in Diagram 28 and immersed in a solution consisting of one part of sulphuric acid to ten parts of water. Let a current from two storage or three dry cells in series C be sent through this arrangement and ammeter A or any low resistant galvanometer being inserted in the circuit as the current flows, hydrogen bubbles will be seen to rise from the negative plate at which the current leaves the solution while the positive plate will begin to turn dark brown; at the same time the reading of the ammeter will be found to decrease rapidly.



Diag. 26 The principle of the storage battery

The brown coating is a compound of lead and oxygen called lead peroxide, which is formed by the action upon the plate by the oxygen which is liberated by the chemical action. Let now the battery be removed from the circuit by opening the key K1 and let an electric bell be inserted in their place by closing the key K2; the bell will ring, and the ammeter A will indicate a current flowing in a direction opposite to that of the original current. This current will decrease rapidly as the energy which was stored in the cell by the original current is expended in ringing the bell. This experiment illustrates the principle of the storage battery. Properly speaking, there has been no storage of electricity, but only a storage of chemical energy. Two similar lead plates have been changed by the action of the current into two dissimilar plates, one of lead and lead peroxide; for any two dissimilar metals in an electrolyte constitutes a primary cell; in this case the lead peroxide corresponds to the copper of an ordinary cell and the lead plate to the zinc. The cell tends to create a current opposite the direction to that of the charging current; that is, its E M F pushes back against the E M F of the charging cell. It was for this reason that the ammeter reading fell when the charging current was removed. This cell acts exactly like the primary cell shown at Diagram 25, and furnishes a current until the thin coating of peroxide is used up; or when the cell is exhausted, the plates return to their metallic condition, and are practically the same, and as there is but little difference in the electrical conditions existing between them they do not deliver any current until the electricity has been passed through the cell so as to change the lead plate to oxide of lead instead of metallic lead. The only

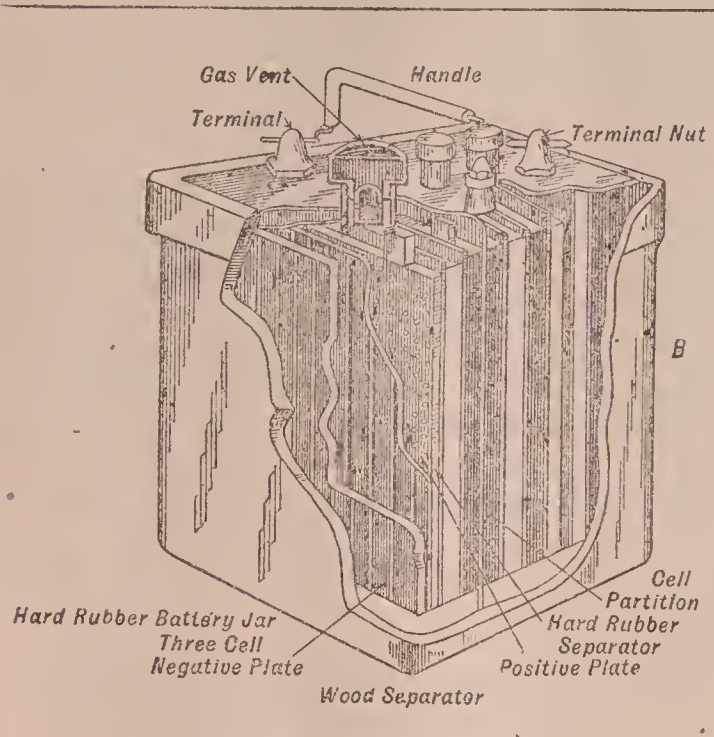
important difference between a commercial storage cell, Diagram 29, and the one shown in Diagram 28 is that means are provided in the making with a much thicker coat of the active material, lead peroxide on the positive plate, and a porous, spongy lead on the negative, than can be formed by a single charge such as we used in Diagram 28. This material is pressed into interstices in the plates as shown in Diagram 29. The E M F of the storage cell is about 2.2 volts. Since the plates are always very close together and may be given any desired size, the internal resistance is usually small, so that the current furnished may be very large. The usual efficiency of the storage cell is about 75%; that is, only about three fourths as much electrical energy can be obtained from it as is put into it. When storage cells are to be used in automobile work they are combined in a single container as shown at Diagram 30, which is a part section of a commercial storage battery.



Diag. # 29 Lead Plate Storage Cell

The main containing member, a jar of hard rubber, is divided into three parts. Each of these compartments serve to hold the elements comprising one cell; the positive and negative plates are spaced apart by wood and hard

rubber separators which prevent short circuiting between the plates. After the elements have been put in place in the compartments forming the individual cells of the battery, the top of the jar is sealed by pouring a compound of pitch and rosin or asphalt over the plates of hard rubber, which keep the sealing material from running into the



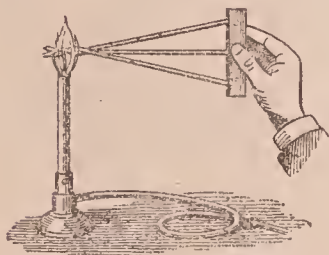
Diag. # 30 A three cell
Storage Battery

cells and onto the plates. Vents are provided over each cell through which gases produced by charging or discharging are allowed to escape. These are so formed that while free passage of gas is provided for, it is not possible for the electrolyte to splash out when the vehicle is in motion. It will be evident that this method of sealing would not be practical on a cell where the members attacked by the acid have to be replaced from time to time, but in a storage battery only the electrolyte needs to be removed. When the plates are discharged they are regenerated by the passing of a current of electricity through them; new electrolyte can be easily inserted through caps in which the vents are screwed. The cells, of which a storage battery is composed, are joined together at the factory with bars of lead which are burned in place, and only two free terminals are provided by which the battery is coupled to the outer circuit. The capacity of a storage battery depends upon the size and the number of plates per set, while the potential or voltage is determined by the number of cells joined in series from the battery. Each cell has a difference of potential of two and two tenths volts when fully charged; therefore, a two-cell battery will deliver a current of 4.4 volts, and a three cell type as shown at Diagram 30 will give about 6.6 volts, between the terminals. Diagram 30 shows each cell as composed of four plates and their separators; two of the plates are positive, the remaining two negative members; the size of storage battery to be used depends upon the number of cylinders of the engine or the specific kind of work it is called upon to do. Four cylinder motors usually take a 6 volt, 60 ampere hour battery, but it is desirable to supply a 6 volt battery having 80 ampere hour capacity for six cylinder motors.

To-day in modern automobile construction the storage battery performs a very important job in the starting and lighting and ignition systems; therefore it is very important for one who wishes to understand the electrical systems of the automobile to thoroughly understand how electrical currents are produced by the chemical generator.

CHAPTER 7. CONDUCTORS AND INSULATORS.

The Transference of Heat, or Conduction in Solids.—If one end of a short metal bar be held in the fire the other end soon becomes too hot to hold; but if the metal rod is replaced by one of wood or glass, the end away from the flame will not be appreciably heated. This experiment and others like it show that nonmetallic substances possess a much smaller ability to conduct heat than do metallic substances; but, although all metals are good conductors as compared with nonmetals, they differ widely among themselves in their conducting powers. Let copper, iron, and German silver wire, twelve inches long, and about one eighth inch in diameter be twisted together at one end, as in Diagram 31, and let a Bunsen flame be applied to the twisted ends. Let a match be slid slowly from the cool end of each wire towards the hot end until the heat from the wire ignites it; the copper will be found to be the best conductor, and the German silver the poorest.



Diag. 31 Differences in heat conductivities of metals

How Electricity is Transmitted.—Electricity produced in one place may be transmitted to another place provided a path is arranged so that it may return to where it started from. It will not flow if there is no circuit, that is, a continuous path. If the circuit is broken, the flow will immediately stop, and will not start again until the circuit is once more completed. Copper wire is usually used to take the electric current from where it is produced to the place where it is to be used, and another wire may be used to bring it back again. The first wire being called the lead and the second the return. If there is any way in which the current may leak from the lead wire and return to the starting point without going through the entire circuit, it will do so, and this leakage is called a "short

circuit." Anything that will permit a current of electricity to pass through it is called a "conductor." All metals are conductors. Substances such as rubber, china, porcelain, glass, wood fiber, and mica are called nonconductors, or insulators. A wire is insulated to prevent the current of electricity from escaping by wrapping it with cotton or silk, which is soaked with rubber to prevent dampness from getting in. When dry, cotton and silk are insulators; but as water is a conductor, damp cotton and silk cease to be insulators. Water, dampness, and oil are good conductors of high voltage currents, but are poor conductors under one hundred volts. While all metals are conductors, some are better than others. A copper wire, for instance, will pass a larger current than an iron wire of the same size, due to the fact that copper has a lower resistance. If a wire has more electricity passed through it than it can easily conduct, heat may be generated, and it will get so hot it will melt. The larger a wire is the larger the current that it can pass without heating. Copper is in most general use as a conductor of electricity because it will permit larger currents to pass than almost any other metal. Silver is a better conductor, but cannot be used because of the expense.

CHAPTER 9. FUNDAMENTAL LAWS OF ELECTRICITY.

These should be mastered by anyone who contemplates becoming an electrician or an ignition man.

1st; A current of electricity must always have a complete circuit.

2d; You have always got a complete circuit as long as the voltage or pressure is high enough to force the current through the resistance.

3d; A current of electricity must always return to its starting place.

4th; A current of electricity always takes the path of the least resistance.

CHAPTER 10. THE PRINCIPLE OF THE DYNAMO AND MOTOR.

Currents Induced by a Magnet.—Let four or five hundred turns of number 22 copper wire be wound into a coil C, as shown at Diagram 32 about 2½ inches in diameter; let this coil be connected into circuits with a simple detector made by suspending in a box



Diag. 32 Induction of electric currents by magnets

with number 40 copper wire a coil of 200 turns of number 30 copper wire; see Diagram 32. Let the coil C be thrust suddenly over the north pole of a strong horseshoe magnet, the deflection of the pointer P of the detector will indicate a momentary current flowing through the coil. Let the coil be held stationary over the magnet; the pointer will be found to come to a rest in its natural position. Now let the coil be removed suddenly from the pole; the pointer will move in a direction opposite to that of its first deflection,

showing that a reverse current is now being generated in the coils. We learn, therefore, that a current of electricity may be induced in a conductor by causing the latter to move through a magnetic field, while a magnetic field has no such influence upon a conductor, which is at rest with respect to the field. This discovery, one of the most important in the history of science, was announced by the great Faraday in 1831. From it have sprung directly most of the modern industrial developments of electricity.

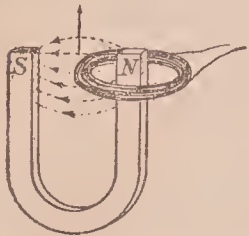
CHAPTER 11. DIRECTION OF INDUCED CURRENTS.

The Lenz Law.—In order to find the direction of the induced current let a small current from a primary cell be applied to the terminals A and B at Diagram 32, and note the direction in which the pointers move when the current enters, say at A. This will at once show in what direction the current was flowing in the coil C when it was being thrust over the north pole. By a simple application to C of the right hand rule as illustrated in Diagram 21, we can tell which is the north and which is the south face of the coil, when the induced current is flowing through it. In this way it will be found that if the coil was being moved past the north pole of the magnet, the current induced in it was in such a direction as to make the lower face of the coil a north pole during the downward motion, and a south pole during the upward motion. In the first case the repulsion of the north pole of the magnet and the north pole of the coil tend to oppose the motion of the coil while it is moving from A to B, and the attraction of the north pole of the magnet and the south pole of the coil tends to oppose the motion while it is moving from B to C. In the second case the repulsion of the two north poles tends to oppose the motion between B and C, and the attraction between the north pole of the magnet and the south pole of the coil tends to oppose the upward motion from

B to A. In every case, therefore, the motion is made against an opposing force. From these experiments, and others like them, we arrive at the following law:

WHENEVER A CURRENT IS INDUCED BY THE RELATIVE MOTION OF A MAGNETIC FIELD IN A CONDUCTOR, THE DIRECTION OF THE INDUCED CURRENT IS ALWAYS SUCH AS TO SET UP A MAGNETIC FIELD WHICH OPPOSES THE MOTION.

This is the Lenz Law. This law might have been predicted at once from the principle of the conservation of energy, for this principle tells us that since an electric current possesses energy, such a current can appear only through the expenditure of mechanical work, or some other form of energy.

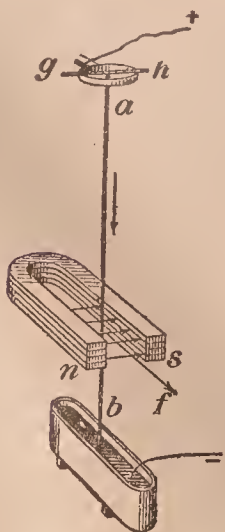


Diag. 33 Currents induced only when conductor cuts lines of force

Conditions Necessary for an Induced E M F.—Let the coil be held in the position shown in Diagram 33 and moved back and forth parallel to the magnetic field; that is parallel to the lines from north to south. No current will be induced by experiments of this sort. It is found that an E M F is induced in a coil only when the motion takes place in such a way as to change the total number of magnetic lines of force, which are inclosed by the coil; or, to state this rule in a more general form, the **LAW OF INDUCTION; WHENEVER A LOOP OF WIRE FORMING A CLOSED CIRCUIT IS PLACED IN A MAGNETIC FIELD, A CURRENT OF ELECTRICITY OR E M F WILL APPEAR IN THE WIRE WHENEVER THE STRENGTH OF THE MAGNETIC FIELD CHANGES; OR, WHEN THE WIRE OR CONDUCTOR IS PASSED**

THROUGH THE MAGNETIC FIELD SO THAT IT CUTS THE LINES OF FORCE AT RIGHT ANGLES. You must pay very close attention to the law of induction, and be very careful not to get the flow of magnetism confused with the flow of electricity, as the two are very easily mixed. Thus we find that all mechanical generators and motors depend upon the principle of the **LAW OF INDUCTION.**

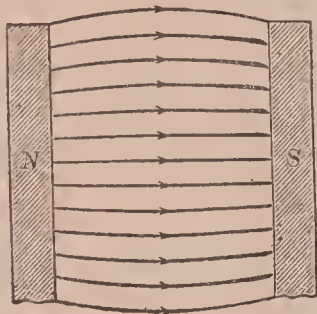
CHAPTER 12. THE PRINCIPLE OF THE ELECTRIC MOTOR.



Diag. 34 The principle of the electric motor

Let the vertical wire A B be rigidly attached to a horizontal wire G H, and let the latter be supported by a ring or other metallic support in the manner shown in Diagram 34 so that A and B are free to oscillate about G and H as an axis; let the lower end of A B dip into a trough of mercury when a magnet is held in the position shown, and a current from a dry cell is sent down through the wire; the wire will instantly move in the direction indicated by the arrow F, viz, at right angles to the direction of the lines of magnetic force. Let the direction of the current in the wire be reversed, the direction of the force acting on the wire will be found to be reversed also. We learn, therefore, that a wire carrying a current in a magnetic field tends to move in a direction at right angles, both in the direction of the field and the direction of the current. This fact underlies the operation of all electric motors.

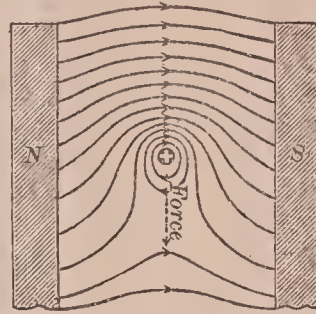
The Motor and Dynamo Rule.—A convenient rule for determining A B, Diagram 34 will move forward or backward in a given case, may be obtained as follows: If the fields of a magnet alone are represented by Diagram 35, and that due to the current alone by Diagram 36, then the resultant field, when the current bearing wire is placed between the poles of the magnet is that shown in Diagram 37. From the strength of the field above the wire is now the sum of the two separate fields, while the strength



Diag. 35 Field of magnet alone



Diag. 36 Field of current alone



Diag. 37 Field of magnet and current

below it is their difference. Faraday thought of the lines of force as acting like stretched rubber bands; this would mean that the wire in Diagram 37 would be pushed down. Whether the lines of force are so conceived or not, the motor rule may be stated thus:

A current in a magnetic field tends to move away from the side on which its lines are added to those of the field. The dynamo rule follows at once from the motor rule and Lenz law,

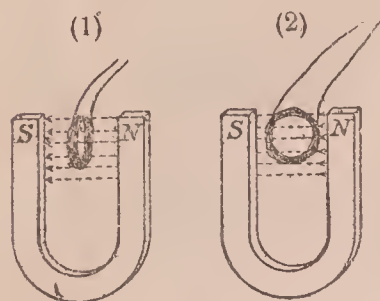
thus when a wire is moved through a magnetic field the current induced in it must be in such a direction as to oppose the motion; therefore,

The induced current will be in such a direction as to increase the number of lines on the side towards which it is moving.

CHAPTER 13. STRENGTH OF THE INDUCED CURRENT, OR E M F.

The strength of an induced current is found to depend simply upon the number of lines of force cut per second by the conductor; or, in the case of a coil, upon the rate of changes in the number of lines of force which pass through the coil. The strength of the current which flows is then given by the Ohms Law; that is, it is equal to the induced current divided by the resistance of the circuit. The number of lines of force which the conductor cuts per second may always be determined if we know the velocity of the conductor and the strength of the magnetic field through which it moves; for, it will be remembered that a field of unit strength is said to contain one line of force per square centimeter; a field of one thousand lines per centimeter in a conductor which is cutting lines at the rate of one hundred million per second, there is an induced current or E M F of one volt. The reason that we used a coil of 500 turns instead of a single turn in Diagram 32 was that by making a conductor in which the current was to be induced cut the lines of force of the magnet five hundred times instead of once, we obtain 500 times as strong an induced current and therefore 500 times as strong a current for a given resistance in the circuit.

CHAPTER 14. CIRCUITS INDUCED IN ROTATING COILS.



Diag. 38 Direction of currents induced in a coil rotating in a magnetic field

Let a 400 or 500 turn coil of a number 28 copper wire be made small enough to rotate between the poles of a horseshoe magnet, and let it be connected into the circuit of the detector precisely as in Diagram 32, starting with the coil in the position as shown in Diagram 38. Let it be rotated suddenly clockwise, looking down from above through 180 degrees; a strong deflection of the detector will be observed. Let it be rotated through the next 180 degrees back to the starting point, and opposite deflection will be observed. The arrangement is a dynamo in miniature. During the first half of revolution the wires on one of the right sides of the loop were cutting the lines of force in one direction, while

the wires on the left side were cutting them in the opposite direction. A current was being generated down on the right side of the coil and up on the left side.

The Dynamo Rule.—Thus, when a wire is moved through a magnetic field, the current induced in it must be in such a direction as to oppose the motion; therefore, the induced current will be in such a direction as to increase the number of lines on the side towards which it is moving. It will be seen that both currents flow around the coil in the same direction. The induced current is the strongest when the coil is in the position shown in Diagram 38-2, because there the lines of force are being cut most rapidly. Just as the coil is moving into or out of the position shown in Diagram 38-1 it is moving parallel to the lines of force, and hence no current is induced, since no lines of force are being cut. As the coil moves through the last 180 degrees of its revolution, both sides are cutting the same lines of force as before, but they are cutting them in an opposite direction, hence the current generated during this last half is opposite in direction to that of the first half.

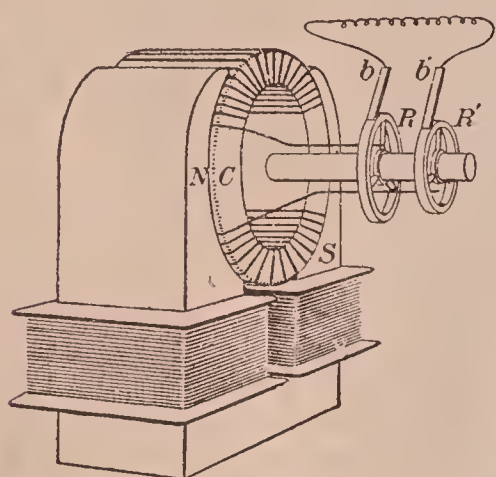
CHAPTER 15. MECHANICAL GENERATORS OR DYNAMOS.

Two distinct types of mechanical generators are in common use, and while their principles of action are practically the same, they differ somewhat in construction and application. The forms first used to succeed the battery were modifications of the large dynamo electrical machine used for delivering current for power and lighting. Later development resulted in the simplification of the dynamo, by which it was made lighter and more efficient, and the modern magneto igniter is the form which has received wide application. A dynamo uses electro-magnets to produce a magnetic field for the armature to revolve in, and is necessarily somewhat heavier and larger than a magneto of equal capacity because the field in the latter instrument is produced by permanent fields. An important advantage in using the magneto form of construction is that the weight of the windings is saved, because the permanent magnets retain their magnetism and do not require the continual energizing that an electro-magnet demands. The dynamo's construction is superior where a continual drain is made upon the apparatus, because if a magneto is used continually the magnets will lose some of their strength, and as the magnetic field existing between the pole pieces decreases in value the amount of the current delivered by the apparatus diminishes in direct proportion. When electro-magnets are used, the constant flow of electric energy through the windings keeps them energized to the proper point, and as current is continually supplied, the strength of the magnetic field remains constant. The dynamo form of generator is used where currents of considerable value are needed, such as in electric lighting and starting systems so widely used now on the automobiles. Where the device is depended upon only to furnish ignition current, the magneto is preferred by most engineers because it is simpler and lighter than the dynamo, and also it may be made in such a form that

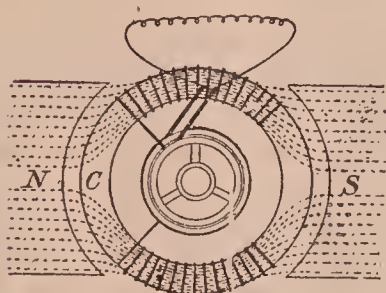
it will comprise a complete ignition system in itself. When a dynamo is utilized the conditions are just the same as far as necessary auxiliary apparatus is concerned, as though batteries were used, and one merely substitutes a mechanical generator in place of the chemical cells. The same auxiliary apparatus necessary in one case is employed in the other as well. A dynamo or magneto produces electricity by an inductive action, which is a reversal of the phenomenon by which a current of electricity will appear in a conductor which is placed in a magnetic field whenever the strength of the field is changed.

CHAPTER 16. DYNAMOS.

A Simple Alternating Current Dynamo.—The simplest form of commercial dynamo consists of a coil of wire so arranged as to rotate continuously between the poles of a powerful electro-magnet, as shown in Diagram 39. In order to make the magnetic field



Diag. 39 Ring-wound armature



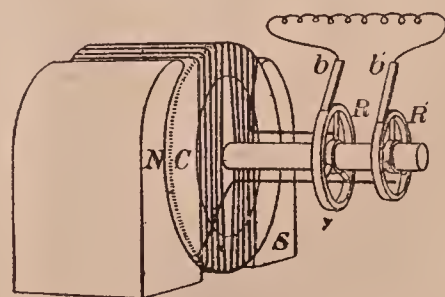
Diag. 40 End view of ring armature

in which the conductor is moving as strong as possible, the coil is wound around an iron core C. This greatly increases the total number of lines of magnetic force which passes between N and S, for the core offers an iron path as shown in Diagram 40, instead of an air path. The rotating parts consist of the coil with its core which is called the armature. If the coil is wound in the manner shown in Diagram 39 and 40, the armature is said to be of the ring type. If in the manner shown in Diagram 41, it is said to be of the drum type, as also in Diagram 42. The drum form of winding is used almost exclusively in modern machines; one end of the coil is attached to the insulated metallic ring R, which is attached rigidly to the shaft of the armature, and therefore rotates with it, while the other end of the coil is attached to a second ring R'. The brushes B and B, which constitute the terminal of the external circuit, are always in contact with these rings. As the coil rotates an induced alternating current passes through the circuit. This current reverses direction as often as the coil passes through the position shown in Diagram 40 and 42; that is the position in which the conductors are moving parallel to the lines of force, for at the instant the conductors which were moving up begin to move down, and those which were moving down begin to move up, the current reaches its maximum value when the coils are moving to a position 90

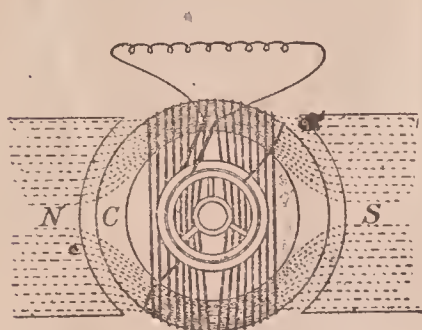
degrees farther on, for then the lines of force are being cut most rapidly by the conductor on both sides of the coil.

The Multipolar Alternator.—For most commercial purposes it is found desirable to have 120 or more alterations of current per second. This could not be attained easily with two pole machines like those sketched from Diagram 39 to 42, hence, commercial alternators are usually built with a larger number of poles alternately, then N and S arranged around the circumference of a

degrees farther on, for then the lines of force are being cut most rapidly by the conductor on both sides of the coil.



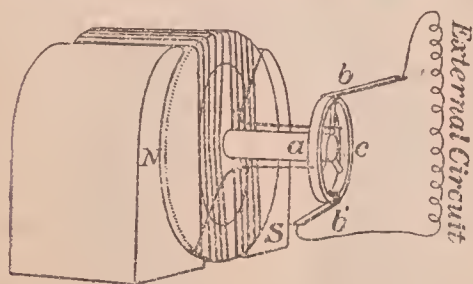
Diag. 41 Drum-wound armature



Diag. 42 End view of drum armature

arrows in the Diagram 43. The current reverses direction at the instant at which all the coils pass the midway point between north and south poles. The number of alternations per second is equal to the number of poles multiplied by the number of revolutions per second. The field magnets N and S of such a dynamo are usually excited by a direct current from some other source.

The Principle of the Commutator.—By the use of a so-called commutator it is possible to transform a current which is alternating in the coil of the armature to one which always flows in the same direction through the external portion of the circuit. The simplest possible form of such a commutator is shown in Diagram 44. It consists of a single metallic ring which is split into two equal insulated semicircular segments, A and

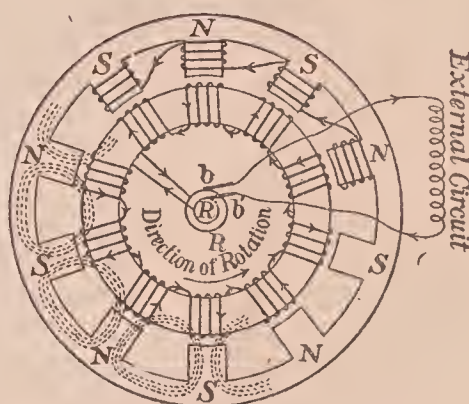


Diag. 44 The simple commutator

always go in the same direction through the external circuit. It would be of a pulsating rather than a steady character, for it would rise to a maximum and fall again to zero twice during each revolution of the armature. This effect is avoided in the commercial direct-current dynamo by building a commutator of a large number of segments instead of two, and connecting each to a portion of the armature coil in the manner shown in Diagram 45.

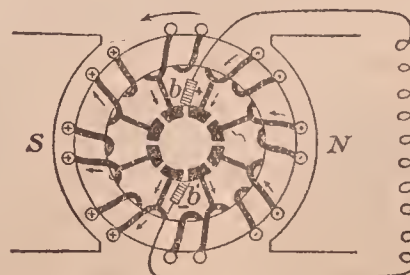
The Ring Armature Direct Current Dynamo.—Diagram 45 illustrates the construction of a commercial two-pole direct current dynamo of the ring armature type. The figure represents an end

circle in the manner shown in Diagram 43. The dotted lines represent the direction of the lines of force through the iron. It will be seen that the coils which are passing beneath north pole have induced current set up in them. The direction of which is opposite to the currents which are induced in the coils which are passing beneath south pole. Since, however, the direction of windings of the armature coil change between each two poles, all the inductive efforts of all the poles are added to the coils, and constitute at any instant one single current flowing around the complete circuit in the manner indicated by the

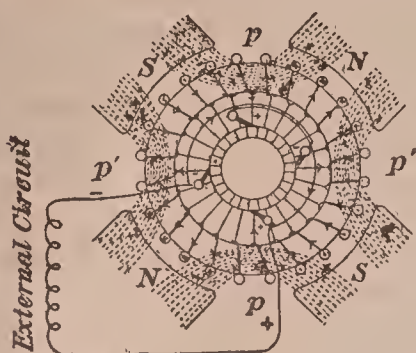


Diag. 43 Diagram of alternating-current dynamo

C. One end of the rotating coil is soldered to one of these semicircles, and the other end to the other semicircle. Brushes B and B are set in such positions that they lose contact with one semicircle and make contact with the other at the instant at which the current changes direction in the armature; the current, therefore, always passes out to the external circuit through the same brush, while a current from such a coil and commutator as that shown in Diagram 44 would



Diag. 45 Two-pole direct-current dynamo with ring armature

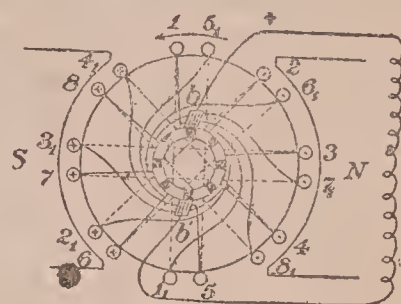


Diag. 46 Four-pole direct-current dynamo, ring-armature type

there any current induced in the conductors at the top and bottom of the rings where the motion is parallel to the magnetic lines. The addition of these similarly direct currents in the various convolutions of the continuous coil on the left side of the ring constitutes one single current flowing upward towards the brush B, (see arrows). On the right half of the ring on the other hand the induced currents are all in the opposite direction; that is, towards the reader, since the conductors are here all moving up instead of down. The dots in the middle of these conductors represent the heads of an approaching arrow. The summation of these currents constitutes one single current, also flowing upward in the right half of the coils towards the brush B. These two currents form the two halves of the ring, pass out at B through the external circuit, and back at B. This condition always exists, no matter how fast the rotation, for it will be seen that as each loop rotates into the position where the direction of this current reverses, it passes a brush and therefore, at once becomes a part of the circuit on the other half of the ring where the currents are all flowing in the opposite direction. If the machine is of the four-pole type like that shown in Diagram 46, the current flows towards two mutual points or points of no induction instead of towards one as in two-pole machine, and they flow away from two other neutral points, see p p p p, Diagram 46, hence there are four brushes, two positive and two negative. Since the two positive and two negative brushes are connected as shown, both sets of current flow off to the external circuit on a single wire. The figure with its arrows will explain completely the generation of current by a four-pole machine.

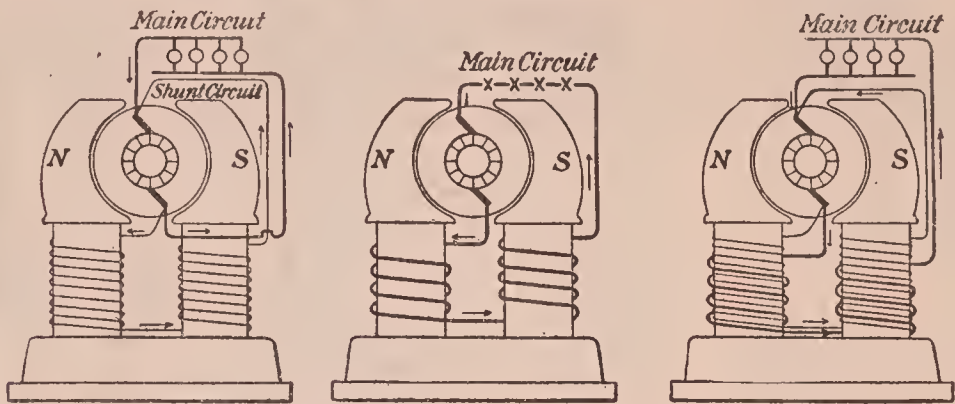
The Drum Armature Direct Current Dynamo.—The drum wound armature shown in section in Diagram 47 has an advantage over the ring armature in that while the conductors on the inside of the latter never cut lines of force and are therefore always idle, in the former all of the conductors are cutting lines of force except when they are passing the neutral points; in theory, however, the operation of the drum armature is precisely the same as that of the ring armature. All of the conductors on the left side of the line connecting the brushes, see Diagram 47, carry induced currents which flow in one direction, while all the conductors on the right side of this line have opposite currents induced in them. It will be seen, however, in tracing out the connections 1 1, 2 2, 3 3, etc., of Diagram 47, the dotted lines represent connections at the back of the drum that the coil is so wound about the drum that the current in both halves are always flowing towards one brush B, from which they are led to the external circuit.

view of a core like that shown in Diagram 39. The coil is wound continuously around the core, each segment being connected to a corresponding segment of the commutator in the manner shown in Diagram 45. At a given instant currents are being induced in the same direction in all the conductors outside of the core on the left half side of the armature. The cross on these conductors representing the tail of a retreating arrow is to indicate that these currents flow away from the reader. No E M F is induced in the conductor on the inner side of the ring since these conductors cut no lines of force. See Diagram 40. Nor is



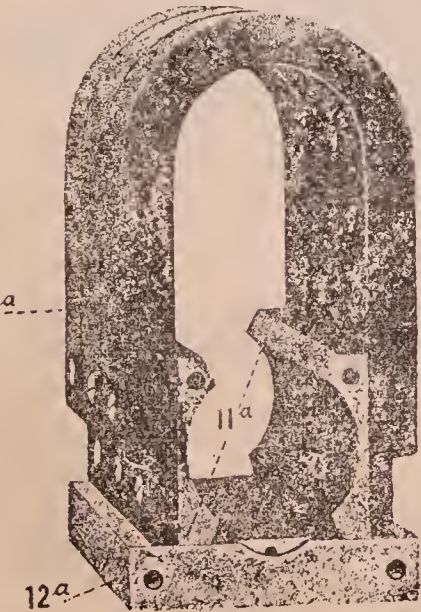
Diag. 47 The direct current Dynamo Drum Winding

Series, Shunt, and Compound Wound Dynamos.—In direct current machines the field magnets N S is excited by the current which the dynamo itself produces. In the so-called shunt wound machines, a small portion of the current is led off from the brushes through a great many turns of fine wire which encircle the core of the magnet, while the rest of the current flows through the external circuit. See Diagram 48. In the so-called Series Wound Dynamo, Diagram 49, the whole of the current is carried through a few turns of coarse wire which encircle the field magnet. These turns are then in series with the external circuit. In the compound wound machines, Diagram 50, there is both a series and a shunt coil. By this arrangement it is possible to maintain a

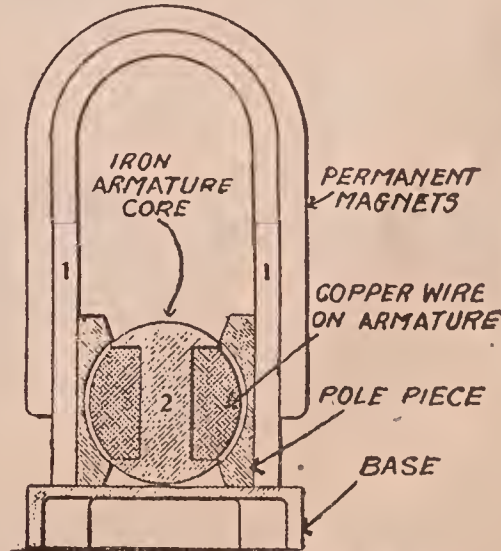


Diag. 48 The shunt-wound dynamo Diag. 49 The series-wound dynamo Diag. 50 The compound-wound dynamo

constant potential difference between the brushes, no matter how much the resistance of the external circuit may be varied, hence, for purposes in which a varying current is demanded, as incandescent lighting and operating of street cars, compound wound dynamos are most exclusively used. In all these types of self-exciting machines there is enough residual magnetism left in the iron core after stopping to start feeble induced currents when started up again. These currents immediately increase the strength of the magnetic field, and so the machine quickly builds up its current until the limits of magnetizing are reached.



Diag. 51. The Permanent magnets. (1a) — The pole pieces. (11a)—The base (12a)—usually of brass or aluminum.



Diag. 52 View of a Low Tension Magneto with the end plate off and armature shown in section.

The Construction of a Low Tension Magneto.—Diagram 51 illustrates the permanent magnets 1-a. The pole pieces 11-a, the base 12-a—usually made of brass or aluminum.

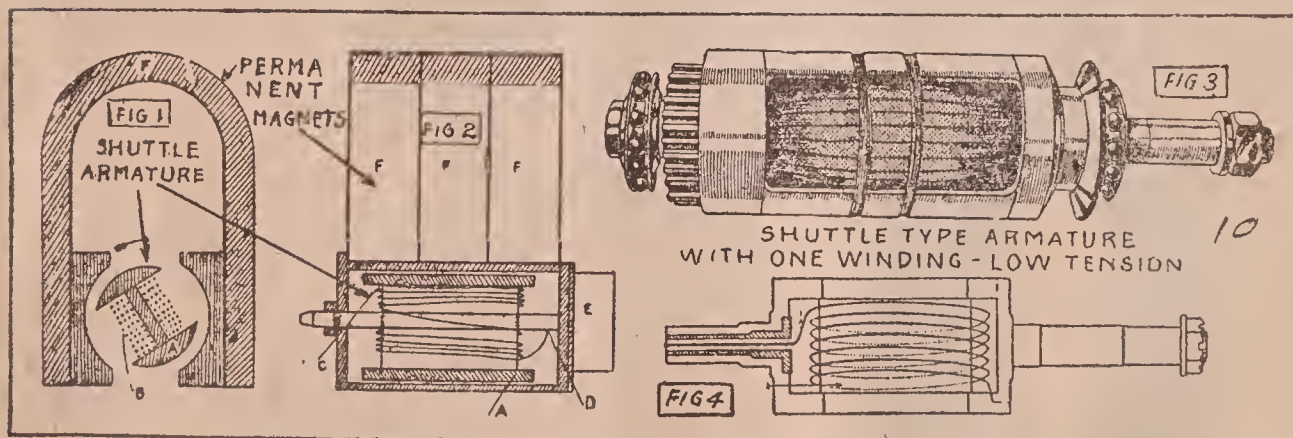


Diag. 53—The Low Tension Magneto complete. View shows the drive end of the armature, which is driven at a fixed speed from crank shaft of engine, by gear or chains.

The armature has one winding.

Diagram 52 is a view of a low tension magneto with the end plates off and the armature shown in section; one, permanent magnets magnetized at all times; two, the armature revolves with a gear connected with the engine shaft. Note that a single winding of insulated copper wire is wound on the armature. Diagram 53 illustrates the low tension magneto, complete view, showing the driving end of the armature which is driven at fixed speed from the crank shaft of the engine, by gears or chain. The armature has one winding. In Diagram 54 the magneto is also a mechanical generator, but the current generated is alternating; that is, the current is not a steady flow, but alternates continuously. The field magnets are always of the permanent magnet type. The armature for generating alternating currents is of two types; the shuttle type, as shown in Figures 3 and 4, and the inductor type which we will take up and explain next. The shuttle type of armature has a primary wire winding of copper wire, one end grounded to the armature core, and the other end insulated as illustrated in Figure 4, Diagram 54.

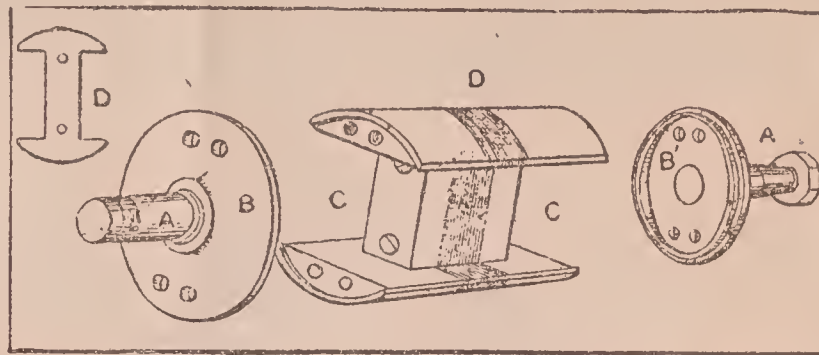
If there is but one winding on the armature it is called a primary winding, and is of low voltage, about six volts; therefore it is called a low tension magneto.



Diag. # 54 The Magneto Mechanical Generator in section

Parts of the Low Tension Magneto Shuttle Type Armature.—Diagram 55 illustrates the necessary parts constituting the shuttle armature, or H type. Bronze heads B B screw to the armature core C and C, shafts A A are driven and riveted to bronze heads; wire is wrapped around the space C and C. It will be seen that the core is not a solid casting; rather, it is a pair of castings between which is clamped a group of soft iron stampings, D, having the form shown in the detailed sketch 55. The object of thus laminating the core, as it is called, is to retard the circulation of eddy currents in the core due to induction. The same forces of induction which are at play in the

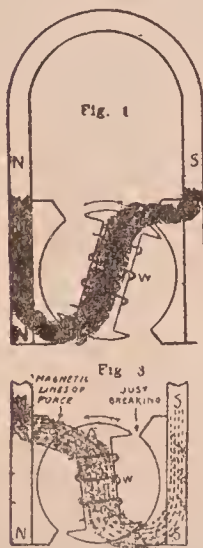
windings operate also in the iron core itself, and if unchecked, would both consume power and heat the armature unduly. As the voltage of the currents is very low,



Diag. 55 Parts of the Low Tension Magneto Shuttle type armature.

even the slight obstruction of the lamination is sufficient to retard them. The laminated section of the armature is shown at D. Laminated means that instead of the casting C being solid there are several layers of flat iron placed together C, as shown at D.

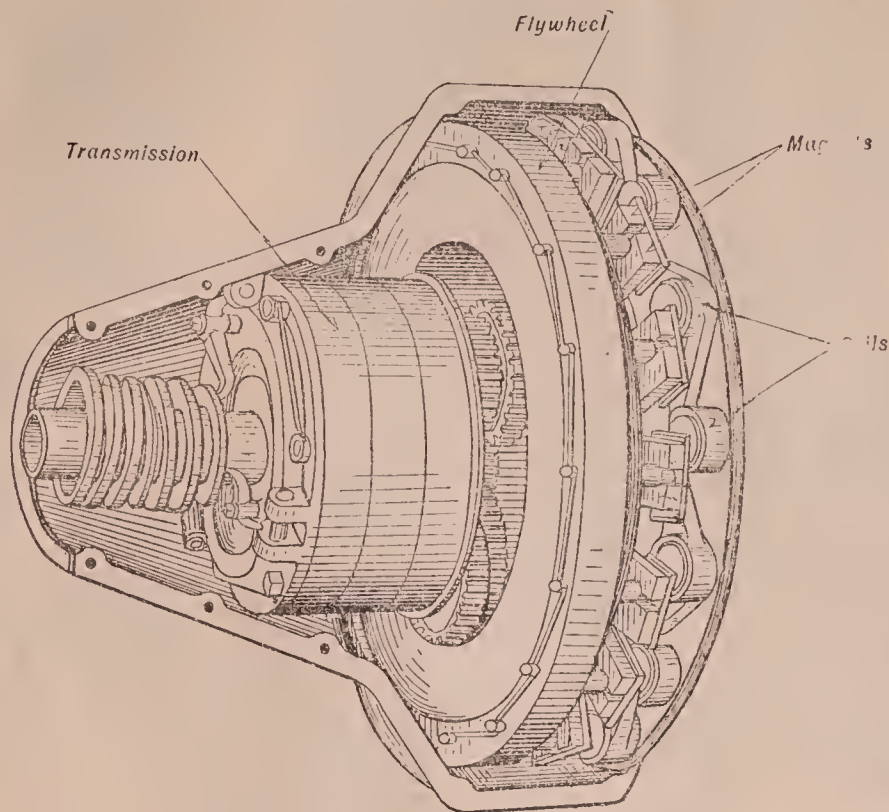
How Currents Are Made to Alternate in the Windings of Armatures.—Referring to Diagram 56, figure 1, the lines of force are passing through the armature upward from N to S and continue until they reach the position shown in Figure 3. The lines will then pass through the armature downward from N to S, thus reversing the flow. This reversal occurs twice during every revolution of the armature. When armature is in the position shown in figure 3 the current strength is at its maximum, and is the position in which it should be placed when the current is broken or interrupted for transforming purposes. As the armature revolves between the pole pieces in the magnetic field, the polarity changes twice in every revolution, which causes the loop of wire or conductor to be in a magnetic field, and the strength of that field is changed twice in a revolution, which causes an impulse or an electric current to appear in the wire, and it is this current which is utilized for creating the magnetic field in the transformer which is further utilized for ignition purposes in the automobile.



Diag. # 56
How the current is made to alternate in the windings of Armature

The Inductor Type Armature Magneto is shown in Diagram 57. This electrical generator is built in such a manner that it forms a part of the power plant. The magnetic field is produced by a series of revolving magnets which are joined to and turn with the fly wheel of the engine. The armature coils are carried by a fixed plate which is attached to the engine base. This apparatus is really a magneto having a revolving field and a fixed armature, and as the magnets are driven from the fly wheel there is no driving connection to get out of order and cause trouble. As the coils in which the current is generated are stationary, no commutator or brushes are needed to collect the current, because the electricity may be easily taken from the fixed coils by direct connection. This type is known as the Ford Magneto. This magneto generates a low voltage of about 6 to 30 volts or slightly more, owing to the speed. The current generated is alternating. This is also called an inductor type armature because the coils of wire, called the stationary armature, remain stationary, and the inductor or magnets, called the rotating field, re-

volve. Instead of there being two impulses per revolution there are sixteen impulses per revolution, because there are sixteen coils and sixteen inductors or magnets. In other words, each revolution of the fly wheel to which the magnets are attached means one revolution of the crank shaft. There are sixteen positions of the magneto when the current output is at its maximum height, and each of these positions is called the peak



Diag. 57 Distinctive Form of Current Producer Used on Ford Cars is Incorporated in the Power Plant Fly Wheel.

of the current wave; there are also sixteen positions, during which the current is not flowing at all; each of these is called the neutral position, and each is half way between two peaks; therefore, every sixteenth of a revolution of the magneto a position is reached where no current is being generated. Each alternating peak or impulse is of an opposite polarity; that is, there are eight positions in each revolution when the current which flows from the magnet windings to the lights is positive, and between these positives are eight other positions when the current is negative; Therefore, the Ford magneto, the shuttle type, low tension magneto, the dynamo, the storage battery, or dry cell, are utilized on the automobile as a means of producing a primary current which would be valueless unless suitable apparatus for stepping up this current, or in other words, transforming it from a low tension current to one of high voltage, and also suitable apparatus for timing and regulating this high tension current so that it can be controlled and be made to appear in the combustion chamber at the proper time.

CHAPTER 17. THE PRINCIPLE OF THE INDUCTION COIL AND TRANSFORMER.

CURRENTS INDUCED BY VARYING THE STRENGTH OF A MAGNETIC FIELD. Let about 500 turns of number 28 copper wire be wound around one end of an iron core as shown in Diagram 58, and connected to the circuit of a galvanometer or current detector; let about 500 more turns be wrapped about another portion of the core and connect into the circuit of two dry cells, when the key K is closed, the deflection of the galvanometer or indicator will indicate that a temporary current has been induced in one direction through the coil S, and when it is opened an equal but opposite deflection will indicate an equal current flowing in the opposite direction. The experiment illustrates the principle of the induction coil and the transformer. The coil P in Diagram 58 which is connected to the source of the current is called the primary coil, and the coil S in which the currents are induced is called the secondary coil, causing the lines of force to spring into existence inside of S; or in other words, magnetizing the space inside of S has caused an induced current to flow in S, and demagnetizing the space inside of S has also induced a current in S with the general principle stated, thus that any change in the number of magnetic lines of force which threads through a coil induces a current in the coil, or **WHENEVER A LOOP OF WIRE FORMING A CLOSED CIRCUIT IS PLACED IN THE MAGNETIC FIELD A CURRENT OF ELECTRICITY WILL APPEAR IN THE WIRE WHENEVER THE STRENGTH OF THE FIELD IS CHANGED.** We may think of the lines as always existent as closed loops which collapse under demagnetization to mere double lines at the axis of the coil. Upon magnetization one of these two lines spring out, cutting the encircling conductor and inducing the current.

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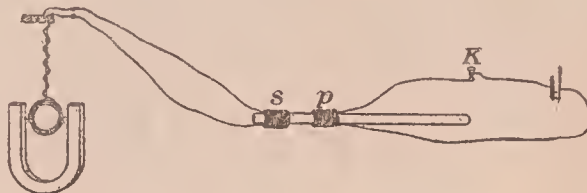


Diagram 58. Induction of current by magnetizing and demagnetizing an iron core.

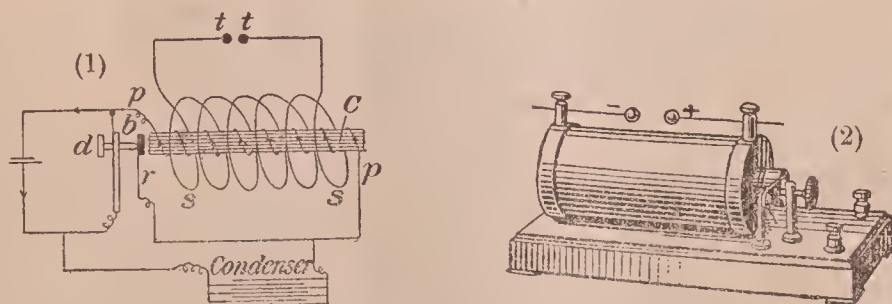
The Direction of the Induced Currents.—The Lenz Law which will be remembered, following from the principle of the conservation of energy, enables us to predict at once the direction of the induced current in the above experiment, and an observation of the deflection of the galvanometer enables us to verify the correctness of the prediction. Considering first the case in which the primary circuit is made, and the core thus magnetized; according to the Lenz Law the current induced in the secondary circuit must be in such a direction as to oppose the change which is being induced by the primary current; that is, in such a direction as to tend to magnetize the core oppositely to the direction in which it is being magnetized by the primary. This means, of course, that the induced currents in the secondary must encircle the core in a direction opposite to the direction in which the primary current encircled it. We learned, therefore, that on making the current in the primary the current induced in the secondary is opposite to that in the primary. When the current in the primary is broken, the magnetic field created by the primary tends to die out; hence, by the Lenz Law the current induced in the secondary must be in such a direction as to tend to oppose the process of demagnetization; that is, in such a direction as to magnetize the core in the same direction in which it is magnetized by the decaying current in the primary; therefore, the current induced in the secondary at breaking the current induced in the secondary is in the same direction as that in the primary.

E M F in the Secondary.—If half of the 500 turns of the secondary as shown in Diagram 58 are unwrapped the deflection will be found to be just half as great as before; since the resistance of the circuit has not been changed we learn from this that

the E M F of the secondary is proportional to the number of turns of wires in it. If we wish to develop a very high current in the secondary we have only to make it of a very large number of turns of fine wire.

Self Induction.—If in the experiment illustrated in Diagram 58 the coil S had been made a part of the same circuit as P, the E M F induced in it by the change in the magnetism of the core would of course have been just the same. In other words, when a current starts in a coil the magnetic field which it itself produces tends to induce a current opposite in direction to that of the starting current; that is, tends to oppose the starting of the current; and when a current in a coil stops, the collapse of its own magnetic field tends to induce a current in the same direction as that of the stopping current; that is, tends to oppose the stopping of the current. This means merely that a current in a coil acts as though it had inertia and opposes any attempt to start or stop it. This inertia-like effect of a coil itself is called self-induction. Let a few dry cells be inserted into a circuit containing a coil of a large number of turns of wire, the circuit being closed at some point by touching two bare copper wires together, holding the bare wires in the fingers; break the circuit between the hands and observe the shock due to the current which the E M F or self induction sent through your body. Without the coil in the circuit you will obtain no such shock, though the current stops when you break the circuit will be many times larger. The spark coil of the automobile is a good illustration of a device for producing a spark due to self induction.

The Induction Coil.—The induction coil as usually made, Diagram 59, consists of a soft iron core, C, composed of a bundle of soft iron wires, a primary coil, P, wrapped around this core and consisting of say 200 turns of copper wire; for example, Number 16, which is connected into the circuit of a battery through the contact points at the end of the screw, D. A secondary coil, S, surrounding the primary in the manner indicated in the diagram and consists generally of between 30,000 and 100,000 turns of number 35 copper wire, the terminals of which are the points T T, and a hammer B or

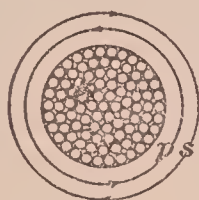


Diag. 59 Induction coil

other automatic arrangement for making and breaking the circuit of the primary. Let the hammer B be held away from the opposite contact points by means of the fingers, then touch to this point, then pull quickly away, a spark will be found to pass between T and T at break only, never at make. This is on account of the opposing influence at make of self-induction in the primary. The magnetic field about the primary rises very gradually to its full strength, and hence its lines pass into the secondary coil comparatively slowly; at break, however, by separating the contact points quickly we can make the circuit at the primary fall to zero in an exceedingly short time, perhaps not more than one hundred thousandth part of a second; that is, we can make all of its lines pass out of a coil in this time, hence the rate at which the lines thread through or cut the secondary is perhaps ten thousand times as great at break as at make, and therefore the E M F is also something like ten thousand times as great. In the normal use of the coil the primary is automatically made and broken at B by means of a magnet and the spring, precisely as in the case of the electric bell. Let the student analyze this part of the coil for himself. The condenser shown in diagram 59, with its two sets of plates

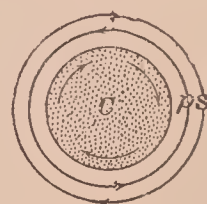
connected to the conductor on either side of a spark gap between R and D, is not an essential part of a coil, but when it is introduced it is found that the length of the spark which can be sent across between T and T is considerably increased. The reason is as follows: when the circuit is broken at B the inertia, that is, the self induction of the primary current, tends to make a spark jump across from D to B, and if this happens the current continues to flow through this spark or arc until the terminals have become separated through a considerable distance. This makes the current die down gradually instead of suddenly, and does not produce a high E M F; but when a condenser is inserted, as soon as B begins to leave D the current begins to flow into the condenser, and this gives the hammer time to get so far away from D that an arc cannot be formed. This means a sudden break and a high E M F. Since a spark passes between T and T only at break it must always pass in the same direction. Coils which give 24 inch spark perhaps 500,000 volts, are not uncommon; such coils usually have hundreds of miles of wire upon their secondaries.

Laminated Cores Foucault Currents.—The core of an induction coil should always be made of a bundle of soft iron wires insulated from one another by means of shellac or varnish, see Diagram 60, for whenever a current is started or stopped in the primary, P, of a coil furnished with a solid iron core, see Diagram 61, the change in the magnetic field of the primary induces a current in the conducting core, C, for the same reason that it induced one in the secondary S. This current flows around the body of the core in the same direction as the induced current in the secondary S; that is, in the direction of the arrows. The only effects of these so-called eddies, or foucault currents, is to heat the core, and this is obviously a waste of energy.

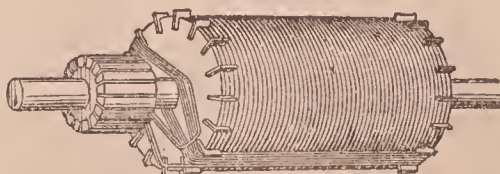


Diag. 60 Core of insulated iron wires.

If we can prevent the appearance of these currents, all of the energy which they would waste in heating the core may be made to appear in the current of the secondary. The core is therefore built of varnished iron wire, which runs parallel to the axis of the coil; that is, perpendicular to the direction in which the current would be induced. The induced E M F therefore finds no closed circuit in which to set up a current. It is for the same reason that the iron cores of dynamos and motor armatures, instead of being solid consist of iron discs placed side by side, as shown in Diagram 62, and insulated from one another by a film of oxide. A core of this kind is called a laminated core. It will be seen that in all such cores the space or slots between the laminations must run at right



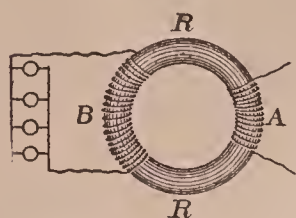
Diag. 61 Diagram showing eddy currents in solid core



Diag. 62 Laminated drum-armature core with commutator, showing one coil wound on the core.

angles to the direction of the induced E M F; that is, perpendicular to the conductor upon the core.

The Transformer.—The commercial transformer is a modified form of induction coil. The chief difference is that the core, R, Diagram 63, instead of being straight is bent

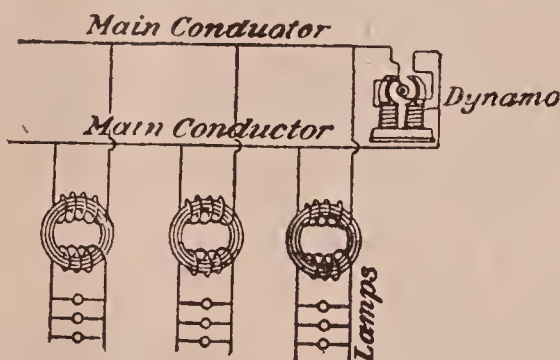


Diag. 63 Diagram of transformer

into the form of a ring, or is given other shapes, such that the magnetic lines of force have a continuous iron path. Instead of being obliged to push out into the air as in the induction coil; furthermore, it is always an alternating current instead of an intermittent current which is sent through the primary A. Sending such a current through A, is equivalent to magnetizing the core first in one direction, then demagnetizing it, then magnetizing it in the opposite direction. The result of these changes in the magnetizing of the core causes the secondary B to be in a magnetic field which is constantly being changed, and as the law of induction states, THAT A LOOP OF WIRE

FORMING A CLOSED CIRCUIT BEING PLACED IN A MAGNETIC FIELD, A CURRENT OF ELECTRICITY WILL APPEAR IN THE WIRE WHENEVER THE STRENGTH OF THE FIELD IS CHANGED, is thus utilized to good advantage.

The Use of the Transformer.—The use of the transformer is to convert an alternating current from one voltage to another, which, for some reason, is found to be more convenient. For example, in electric lighting where an alternating current is used, the E M F generated by the dynamo is usually either 1100 volts or 2200 volts, a voltage too



Diag. 64 Alternating current lighting circuit with transformers

high to be introduced safely into private homes, hence transformers are connected across the main conductor in the manner shown in diagram 64. The current which passes into the house to supply the lamps does not come directly from the dynamo; it is an induced current generated in the transformer.

Pressure in Primary and Secondary.—If there are a few turns in the primary and a large number in the secondary, the transformer is called a step-up transformer, because the voltage produced at the terminals of the secondary is greater than applied at the terminals of the primary; thus an induction coil is a step-up transformer. In electric lighting, however, transformers are mostly of the step-down type; that is, a high pressure, say 2200 volts, is applied at the terminals of the primary, and a low pressure, say 110 volts, is obtained at the terminals of the secondary. In such a transformer the primary will have twenty times as many turns as the secondary. In general the ratio between the voltage at the terminals of the primary and secondary is the ratio of the number of turns of wire upon the two.

Efficiency of the Transformer.—In a perfect transformer the efficiency would be unity. This means that the electrical energy put into the primary, that is, the volts

applied to its terminals, times the amperes flowing through it, would be exactly equal to the energy taken out in the secondary; that is, the volts generated in it times the strength of the induced current; and in fact, in actual transformers the latter produce is often more than 97% of the former; that is, there is less than 3% loss of energy in the transformation. This loss of energy appears as heat in the transformer. This transfer which goes on in a big transformer of huge quantities of power from one circuit to another entirely independent circuit, without noise or motion of any sort and almost without loss is one of the most wonderful phenomenon of modern industrial life.

CHAPTER 18. ELECTRICAL TRANSMISSION OF POWER.

Since the electrical energy produced by a dynamo is equal to the produce of the E M F generated by the current furnished, it is evident that in order to transmit from one point to another a given number of watts, say ten thousand, it is possible to have either an E M F of one hundred volts and a current of one hundred amperes, or an E M F of one thousand volts and a current of ten amperes. In the two cases, however, the loss of energy in the wires which carry the current from the place where it is generated to the place where it is used, will be widely different. If R represents the resistance of this transmitting wire, the so-called line, and C the current flowing through it, the energy wasted in heating the line will be but one hundredth times as much in the case of the high voltage, ten ampere current, as in the case of low voltage and one hundred ampere current; hence for long distance transmissions, where line losses are considerable, it is important to use the highest possible voltage, but on account of the difficulty of insulating the commutator segments from one another, voltage higher than seven or eight hundred cannot be obtained with direct current dynamos.

With alternator generators, however, the difficulty of insulation is very much less, on account of the absence of a commutator. The large, ten thousand horse power alternating current dynamos on the Canadian side of Niagara Falls generate directly twelve thousand volts. This is the highest voltage thus far produced by generators. In all cases where these high pressures are employed they are transformed down at the receiving end of the line to a safe and convenient voltage from 50 to 500 volts by means of step-down transformers. It will be seen from the above facts that only alternating currents are suitable for long distance transmission. Plants are now in operation which transmit power as far as one hundred and fifty miles and use pressure as high as 100,000 volts. In all such cases step-up transformers suited at the power house transfer the electrical energy developed by the generator to the line and step-down transformers suited at the receiving end, transfer it to the motor or lamps which are to be supplied.

The generators used on the American side of Niagara Falls produce a pressure of 2300 volts, for transmission to Buffalo, twenty miles away. This is transformed up to 22000 volts. At Buffalo it is transformed down to the voltage suitable for operating the street car lines and factories of the city. On the Canadian side the generators produce current at 12000 volts as stated, and these are transformed up for long distance transmission to 22,000, 40,000 and 60,000 volts.

CHAPTER 19. IGNITION SYSTEMS OUTLINED.

One of the most important auxiliary groups of the gasoline engine comprising the automobile power plant, and one absolutely necessary to insure engine action, is the ignition system which is the spark of life to the engine, or the method employed of kindling the compressed gas in the cylinder to produce an explosion and useful power. The ignition system has been fully as well developed as other parts of the automobile, and at the present time practically all ignition systems follow principles which have become standard through wide acceptance; therefore, at the present time, all gas engines in automobile construction utilize an electrical ignition system in which the compressed gas is exploded by the heating value of the minute electric arc or spark in the cylinders. Two general forms of electrical ignition systems may be used, the most popular being that in which a current of electricity under high voltage is made to leap a gap or air space between the points of the spark plug screwed into the cylinder.

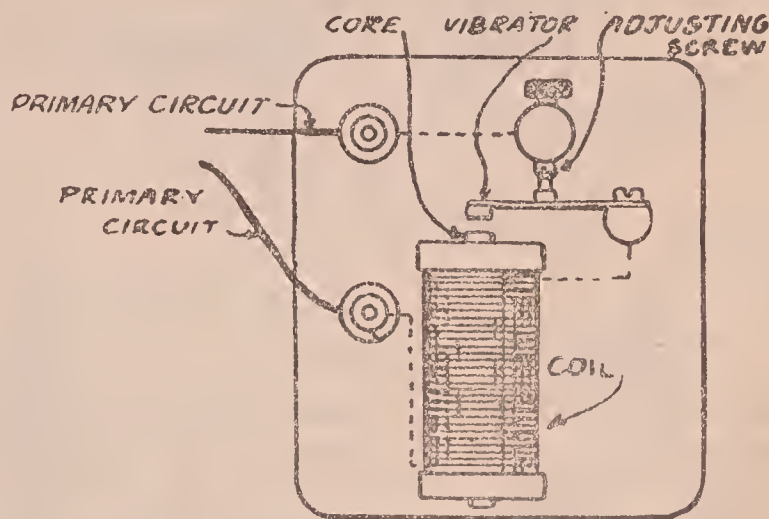
The other form, which has been almost entirely abandoned in automobile practice, but which is used to some extent on marine engines and stationary types, is called the low tension system, because a current of low voltage is used and the spark is produced by moving the electrodes in the combustion chamber. The essential elements of any electrical ignition system, either high or low tension, are first a simple and practical method of current production; second, suitable timing apparatus to cause the spark to occur at the right point in the cycle of engine action; third, it must have a coil or transformer to step up the current so the voltage will be high enough to overcome the resistance in the spark gap in the cylinders and thus produce the arc or spark; fourth, suitable wiring and distributing apparatus and an arrangement in the combustion chamber to produce the spark.

Timer and Distributor Forms.—Anyone familiar with the basic principle of internal combustion engine action will recognize the need of incorporating some device in the ignition system which will insure that the igniting spark will occur only in the cylinder that is ready to be fired at the right time in the cycle of operation. There is a certain definite point at which the spark must take place, this having been determined to be at the end of compression upstroke, at which time the gas has been properly compacted and the piston is about to start returning to the bottom of the cylinder. The Timer is a mechanical switch driven by the engine and is used to connect up or break or interrupt the primary circuit at the time the spark is needed in the cylinders. A distributor is a mechanical switch driven by the engine and is used to distribute the high tension current to the cylinders according to the firing order. These mechanical forms of switches are designed so that hundreds of positive contacts which are necessary to close and open a circuit may be made per minute without failure. When the device is employed to open and close a low tension circuit it is known as a commutator or timer, and when it is used in connection with currents of high voltage they are called secondary distributors. Certain constructional details make one form differ from the other, and while they perform the same function they vary in design. Such timing and distributing devices are always driven by positive gearing from the engine, and are timed so the spark will occur in the cylinders at just the proper time.

The Vibrator; Its Purpose.—As a secondary current in the coil only flows when the primary current begins to flow and is suddenly interrupted, this necessitates an arrangement to complete the primary circuit so that the battery current flowing through the primary winding, and then breaking the circuits so that the battery current stops flowing, or is interrupted from flowing. This causes the SECONDARY WINDING TO BE IN A MAGNETIC FIELD, AND THEN THE STRENGTH OF THE FIELD IS SUDDENLY CHANGED, WHICH PRODUCES A CURRENT IN THE SECONDARY

WINDING which is utilized to jump the gap in the spark plug at the right time if properly controlled. This arrangement is called a vibrator, and it may operate in two different ways, electrical or magnetical, and mechanically.

A Magnetic Vibrator.—The magnetic vibrator depends on the magnetism produced in the core of the coil when the primary current passes, as shown in Diagram 65. A flat spring called the vibrator spring or blade is so placed that one end of it is opposite to the end of the core, the other end being firmly supported. Touching the vibrator spring near its free end is the points of contact with the adjusting screw. When a low voltage current flows through the primary winding the core becomes a magnet and attracts the free end of the vibrator spring, drawing it away from the adjusting screw. As soon

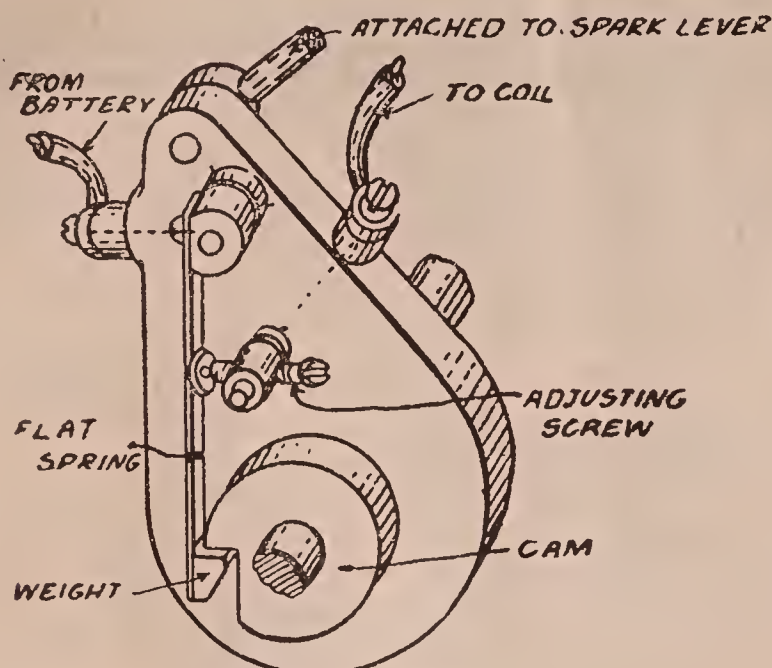


Diag. 65 A Magnetic Type of Vibrator

as the attraction draws the vibrator spring out of contact with the adjusting screw the circuit is broken, the current stops flowing in the primary coil, and the core ceases to be a magnet, and the vibrator spring being no longer attracted by the magnetism it springs back again, making contact with the adjusting screw. This again closes the circuit, and the vibrator spring is again attracted by the magnetism, thus the circuit, through the vibrating springs and adjusting screw is broken and made again as long as the commutator or timer keeps the primary circuit closed through its contact.

Mechanical Vibrator.—A mechanical vibrator is shown in diagram 66. When this type of vibrator is used, the vibrators on the coil are not required, as the vibration of the flat spring against the adjusting screw causes the contact to be suddenly opened and closed by the cam during which time the flat spring vibrates mechanically, causing the primary circuit to be broken, which changes the strength of the magnetic field in the core, thus producing the induced current to flow in the secondary winding of the coil. The mechanical vibrator consists of a flat spring with a small weight on one end, and the other end is attached to a post. The weight rests on the iron rim of a small cam with a notch in it so that when it turns the weight drops into the notch. One wire from the primary circuit is attached to the flat spring, and the other wire of the primary to an adjusting screw. When the weight, called the bob, is in the notch of the cam, the flat spring makes contact with the adjusting screw and the current flows around the primary winding of the core, thus producing the magnetic field, but the cam, in continuing to turn moves the weight out of the notch which separates the flat spring from the screw and breaks the circuit. Because of the springiness of the flat spring, it vibrates

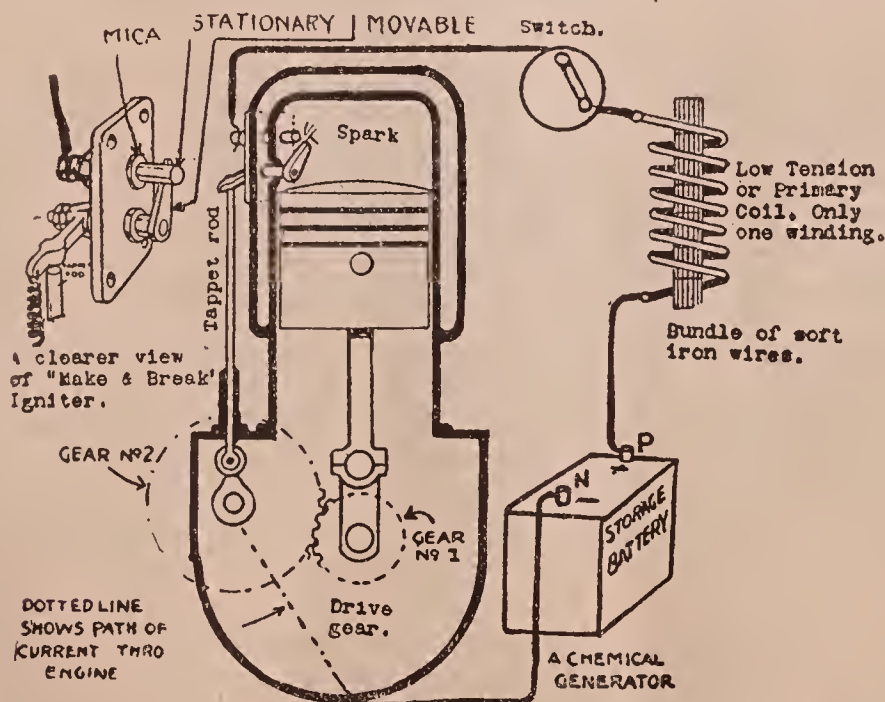
when the weight drops into the notch, making and breaking the current. By making and breaking the contact in this way, the primary flows through the primary winding



Diag. 66-A Mechanical Vibrator

always flowing and stopping each time the vibrator makes and breaks the circuit. This produces a corresponding current in the secondary winding, which is sent to the distributor and there distributed to the cylinders according to the firing order.

Low Tension Coil System of Ignition.—We have learned the different sources from which electricity can be obtained for ignition. The principle of ignition which is the



Diag. 67-A Make and Break Low Tension System of Ignition.

old style make and break igniter uses a low tension or primary coil. This system is seldom used only on stationary engines; however, it will be well for the reader to master

the principles of the low tension coil, as it is the foundation for the building up of a high tension coil or magneto armature winding. The current is strengthened or intensified by the use of a simple coil called a primary or low tension coil. At diagram 67 we have a diagram of a make and break low tension system of ignition. The ignitor is shown which makes and breaks the low tension current as it flows from the positive pole of the battery to the single wound low tension coil through the switch and then through the insulated electrodes in the combustion chamber and then returns through the metal of the engine to the negative ground and there back to where it started from. When the nose of the cam strikes the tappet rod this rod makes and breaks the flow of current and creates a flash or spark which is utilized to set the mixture on fire in the combustion chamber.

Purpose of Spark Plugs.—You are more or less familiar with the ordinary spark plug that is used in connection with the ignition system to produce a spark inside the cylinders of the engine. In Diagram 68 are two views of two typical spark plugs, one showing plug as if it were cut in two, called a sectional view, the other view showing plug disassembled. The metal part of the plug T acts as a conductor of a current while the porcelain C represents the insulating material which is composed of porcelain or

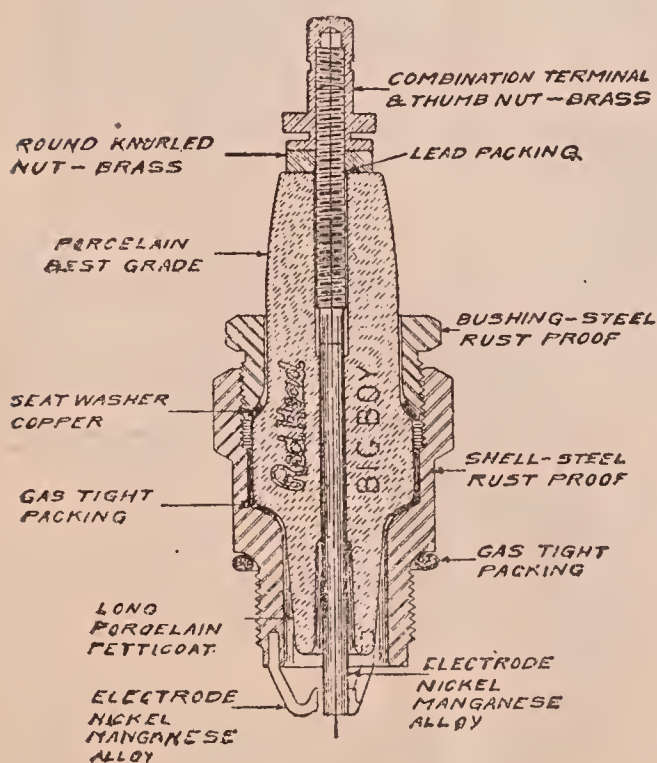


Fig. 2—Names of Parts of Insulated Spark Plug, Especially Made for Magneto Use. Note the heavy terminals. Magnetos give a heavy "fat" spark, but points are set very close. (1/64-inch.)

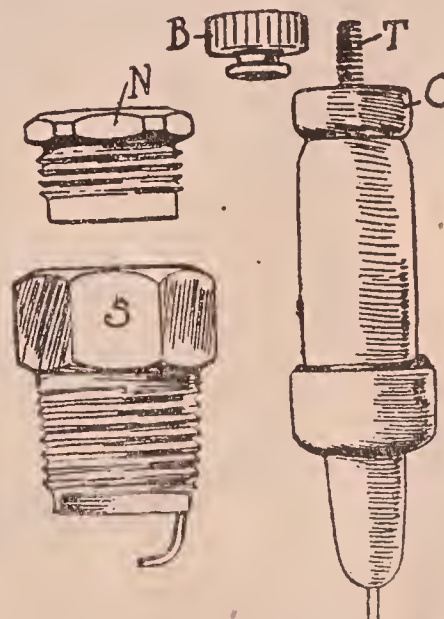


Fig. 3—Parts of a Porcelain Insulated (C), Spark Plug Separated. A Type of Plug Usually used with a Jump Spark Coil System of Ignition. S—Is the iron shell which screws into the engine cylinder.

N—Is the brass bushing which holds the porcelain (C) in the iron shell.

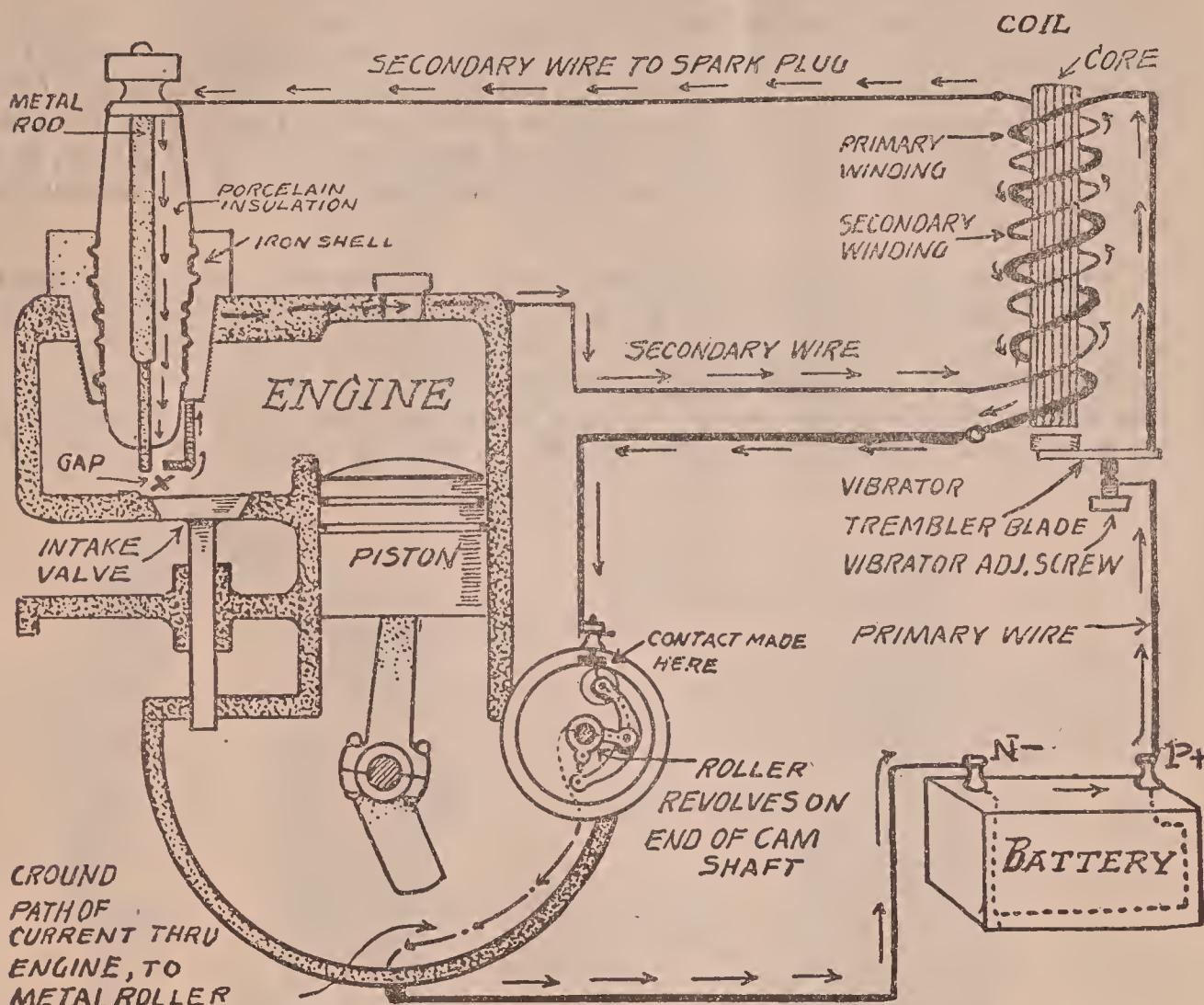
C—Is the porcelain with rod (T) running through it.

B—Is the lock nut or thumb nut which holds the secondary wire. (B) screws on the end of (T) to hold wire in place.

Diag. # 68 Parts and sectional view of a Spark Plug

mica, an insulator of electricity. A spark plug is screwed into each cylinder of the engine, and when the piston is in the right position to receive a spark, a current of electricity is sent along the metal center part, called the firing pin of the spark plug, and across the small air gap at the bottom, and into the outer sleeve. Although this air gap is only about one sixty-fourth to one thirty-second of an inch wide, the air in the gap offers such a tremendous resistance to the current that it requires in the neighborhood of ten to twenty thousand volts of pressure to force a very small quantity of

current across the gap; in other words, the current must be of such high pressure that it will jump across a space between two points, forming a spark as it passes. The current produced by a battery and low tension coil as used on the make and break system would not have enough pressure to jump across this gap; therefore, it must be intensified, or



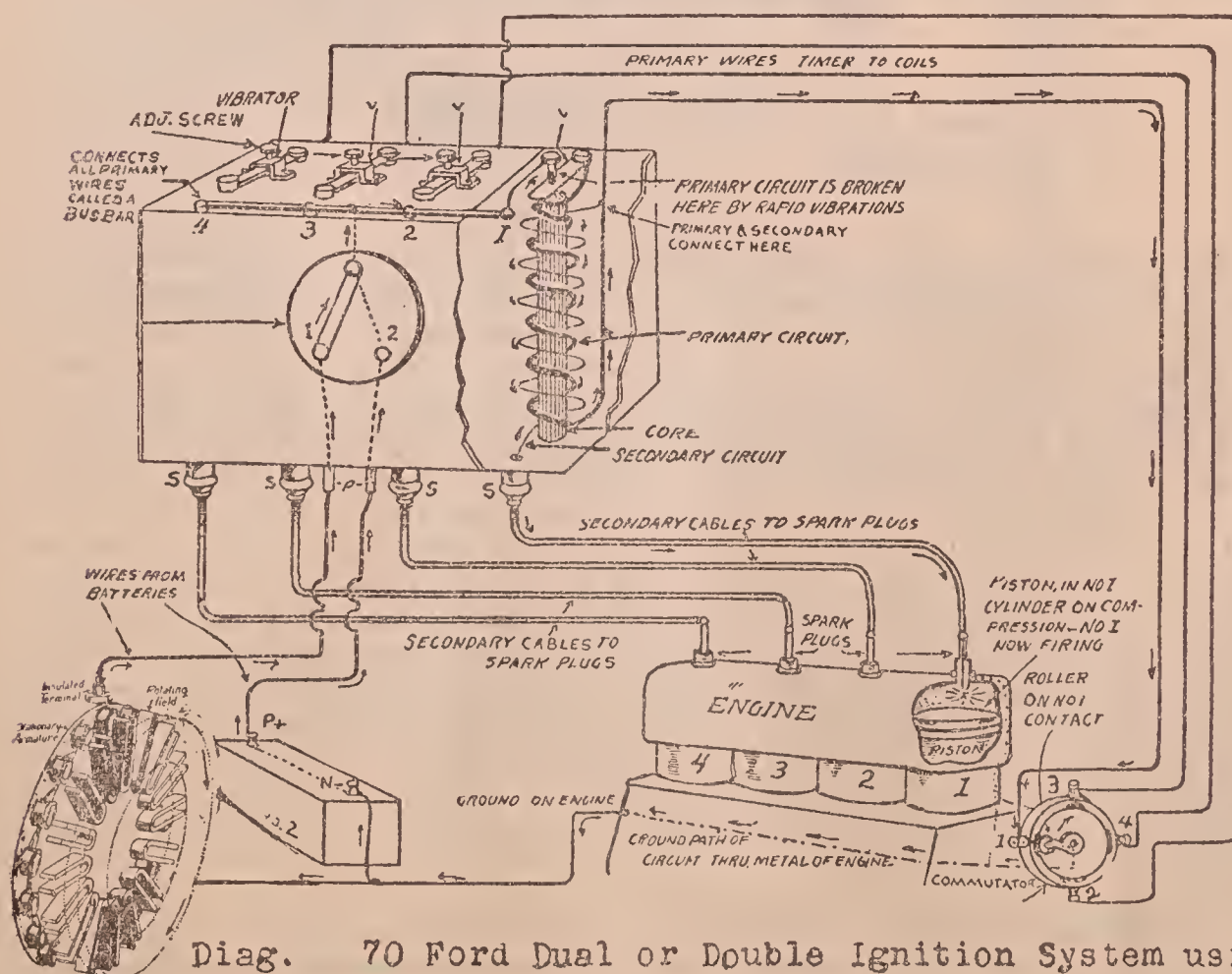
Diag. 69—An exaggerated drawing, made for the purpose of illustrating how the spark plug is screwed into the combustion chamber of the engine, and how the current is carried from the battery through the primary winding of the coil, to commutator etc. Trace the circuit with your pen.

the pressure increased still more. This is accomplished by adding a coil of another kind, called the secondary coil, around the primary coil, and is used to intensify the current sufficiently to force it to jump across the open space; therefore it is called the jump spark or high tension, meaning high pressure.

CHAPTER 20. THE JUMP SPARK OR HIGH TENSION COIL SYSTEM.

Construction of High Tension System.—An induction coil, or jump spark coil consists of a core of soft iron wire over which are wound a few layers of insulated copper wire which is called the primary winding; in other words, this is our original low tension coil as shown in diagram 69. Over the primary winding are wound a great number of layers of exceedingly fine copper wire, insulated, called the secondary winding. When a current of electricity flowing through the primary winding from some source of electrical supply is suddenly stopped and then started again, it will cause a current of great pressure to flow in the secondary winding; although the two windings are not connected, this current is induced or set up by the cause of the change in the magnetic

field. This induced current, set up in the secondary winding, is called the secondary current and flows in waves, there being a wave of current whenever the primary or battery current is stopped and started again by either the magnetic or mechanical vibrator. In diagram 69 the current leaves the positive pole of the battery, flows up and across the vibrating points, then around the primary winding around the core, then out across the timer which is making contact, then returns through the metal of the engine to the ground, and then back to the negative pole of the battery. The completing of this primary circuit causes the iron core to become magnetized, which attracts the trembler blade which separates the vibrating points, thus causing the primary circuit to stop flowing. This causes the iron core to demagnetize, which causes an induced current to rise in the secondary winding and flow out to the center electrode of the spark plug; thus flowing down the firing pin of the spark plug it jumps the gap, grounds through the metal of the engine and thus returns over the ground back to where it started from. Thus a current flows around the secondary circuit every time the circuit is made or broken at the vibrating point. The position of the spark plug in the cylinder can be placed as follows, over the center of the piston, over the exhaust valve, or over the inlet valve. The first position is not the best, as it is found that it too easily becomes foul; if screwed above the exhaust it will likely misfire. This is on account of the dead gases surrounding it. The correct position is over the inlet valve, as it will be kept cool by the inrush of fresh gases and it is in an atmosphere perfectly suited for explosion. This has been found the most suitable place for the spark to appear, as it is the more perfectly cleaned part of the cylinder, and in the direct path of the fresh gases. The plug is usually placed over the inlet valve on T and L head cylinders. In overhead valve types the plugs are placed in the top or on the side of the cylinder; they

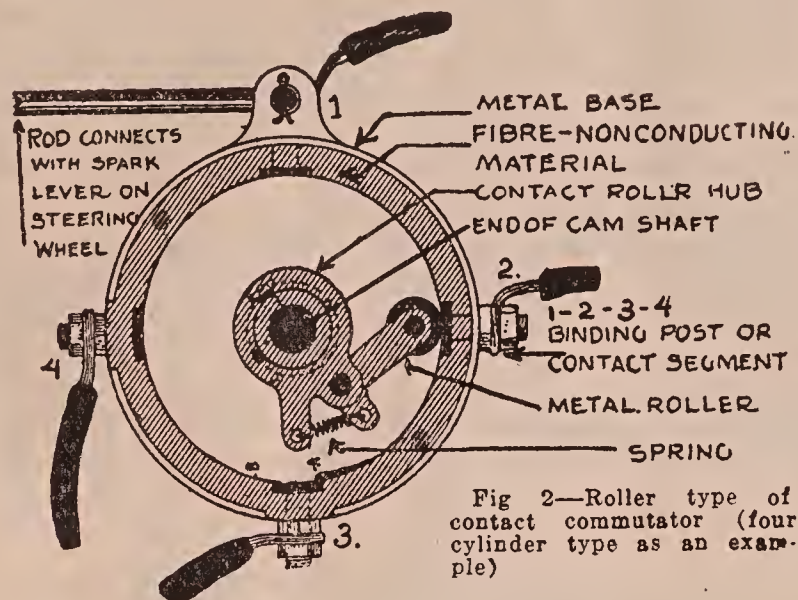


Diag. 70 Ford Dual or Double Ignition System using the Four Vibrator Coils and Commutator

are exposed to the full heat of the explosion, consequently in a high compression engine of this type a well-made plug must be used. Many of the overhead valve engines have the plugs in the side of the combustion chamber.

CHAPTER 21. THE FOUR VIBRATING COIL SYSTEM OF IGNITION USED ON THE FORD.

Dual System.—At Diagram 70 the illustration there will explain from the wiring connection from the battery or magneto through the entire primary circuit. In order



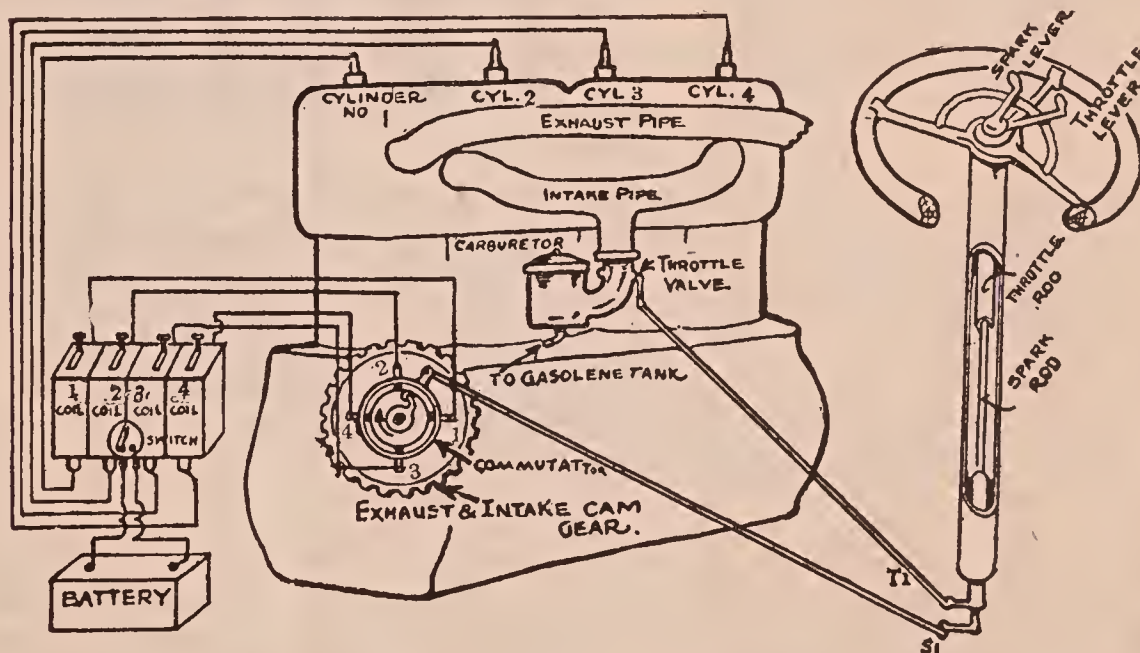
Diag. # 71 Commutator or timer Construction

to clearly understand what the current travels through, place your pencil on the drawing at the positive pole of the battery or the insulated terminal of the magneto. Remember now, and at all times, that there are certain necessary parts which always have to be in the primary circuit; as the current leaves the source, which can be either a mechanical generator or a chemical generator, it passes over the wire to the ignition switch. From the ignition switch it must go around the primary winding on the iron core; it must then go through the timer or commutator and return to where it started from. The commutator or timer is a mechanical switch which is generally driven on the end of the cam shaft, and is used to connect up the primary circuit at the instant the piston gets in firing position. As soon as the primary circuit is complete the trembler blade is pulled down, thus separating the platinum points, which, when together, form a part of the primary circuit. When broken for an instant causes the primary circuit to cease to flow, which causes a sudden change in the strength of the magnetic field, and this produces an induced current in the secondary winding, which flows out through the secondary cable to the spark plugs, there jumps the gap in the spark plug and then returns over the primary wire which is connected to the timer back to where the primary and secondary are connected together; there it returns into the secondary from whence it started.

Commutator or Timer Construction.—Diagram 71 shows a very plain view of the commutator or timer which is used on the Ford. The metal contacts in the fiber housings to which the wires from the coils are connected are called segments. There are as

many segments in the timer or commutator as there are cylinders. These segments are placed certain distances apart, according to the number of cylinders. For instance, a two-cylinder commutator would have two contacts. These two segments would be placed 180 degrees apart. If a single cylinder engine, only one spark is necessary during two revolutions of the crank shaft, therefore the contact roller would revolve one half the speed of the crank shaft, and would be placed 360 degrees apart, or one contact segment. On a four-cylinder engine there would be four contacts, placed 90 degrees apart, as shown in Diagram 71. Because a contact roller revolves one half the speed of the crank shaft there would be four sparks during two revolutions of the crank shaft. If a six-cylinder engine, six impulses or contacts are necessary during two revolutions of the crank shaft; therefore, the roller contact would revolve one half speed of the crank shaft also. The contact segments would be placed 60 degrees apart; on an eight cylinder engine, the contact would be 45 degrees apart on a twelve cylinder engine. The segments are insulated in a fiber housing which only permits the primary circuit to be connected up when the metal roller is making contact with the segment.

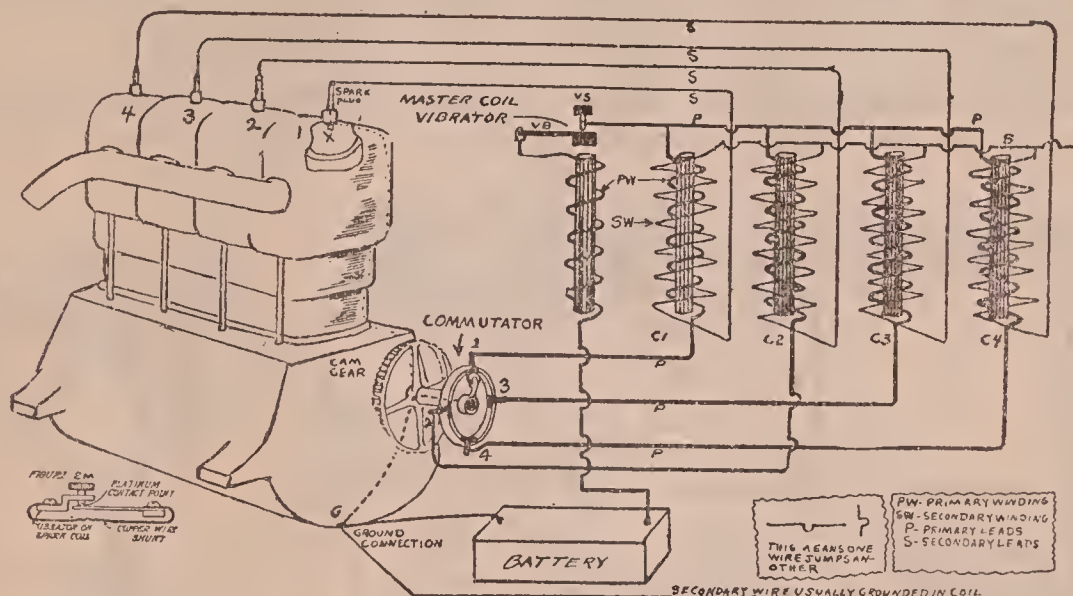
How the Commutator or Timer Helps Control the Speed.—The commutator or timer is connected with the spark lever on the steering wheel as shown in diagram 72. When



Diag. # 72 Show how timer or commutator Control the appearance of the spark in the Combustion Chamber

the spark lever is pushed forward the commutator is shifted forward so that the metal roller makes contact earlier with the contact segments. This is called advancing the spark. If the commutator is shifted back instead of forward, the contact is made later; this is called retarding the spark. There are two methods of advancing and retarding the spark; this is either done by the hand spark lever or it is automatically controlled by a governor. It is well to run with the spark lever as well forward or advanced as possible, as it will tend to keep the speed of the engine up and consume less gasoline and create less heat. If the spark lever is too far advanced then the engine will pound, or knock, because the ignition will take place before the piston is over top dead center. The amount of advancing or retarding of the hand spark lever in order to get the best results, must be learned by actual practice.

The Master Vibrator.—At Diagram 73 is illustrated a Master Vibrating Coil on a 4-cylinder engine. The purpose of the master vibrator coil is to do the vibrating for the other coil; for instance, quite often multiple cylinder coils with several vibrators cause considerable trouble from the sticking or welding together of the platinum points, causing missing. Where a multiple unit coil is used a great deal of care must be exercised to keep them in proper adjustment by placing a single wound master vibrator coil in series with the primary circuit and by short circuiting all of the vibrators in the coils the one master vibrator will do the work for the others. It will be noticed, however, the other coils are used for producing the high tension current; also note there is but one winding on the master vibrator coils; its purpose merely being that of vibrating and changing the strength of the magnetic field in the other four coils.



Diag. # 73 A Master Vibrator coil on a four cylinder engine

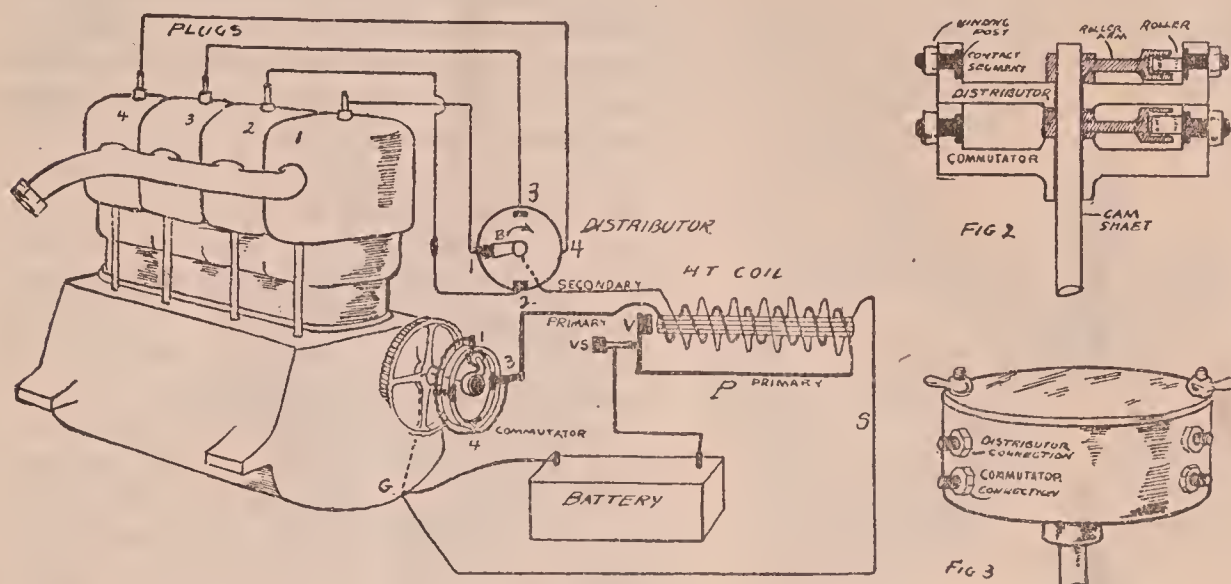
At diagram 73 it will be noted the firing order is 1-3-4-2. Number 1 cylinder is now firing as coil c-1 and the contact on the segment commutator number 1 are in operation. The next cylinder fire will be number 3. Note all the secondary wires are grounded on one end; this is usually done in the coil box; all connections being made to a binding post. A ground wire is then run to the frame of the engine from the binding post.

CHAPTER 22. THE DISTRIBUTOR OR SYNCHRONOUS SYSTEM OF IGNITION.

In the foregoing examples it will have been noted that the amount of wiring required for motors having more than one cylinder becomes increasingly complicated. A system now generally used, known as the distributor system, very considerably simplifies the wiring, and at the same time more accurate timing of firing of the respective cylinders is obtained.

At Diagram 74 one trembling coil only is necessary; this having the high tension terminal joined to the distributor which is a special form of rotating switch highly insulated which distributes the high tension current to the cylinders according to the firing order. The distributor arm and brush B rotate at the same speed as the commutator roller contact maker and in perfect unison with it; that is to say, when the following low tension current is completed, the high tension current is completed likewise. The

diagram should make the system clear; it being borne in mind that the distributor is rotating as well as the contact maker, and in perfect synchronism; or to state it more



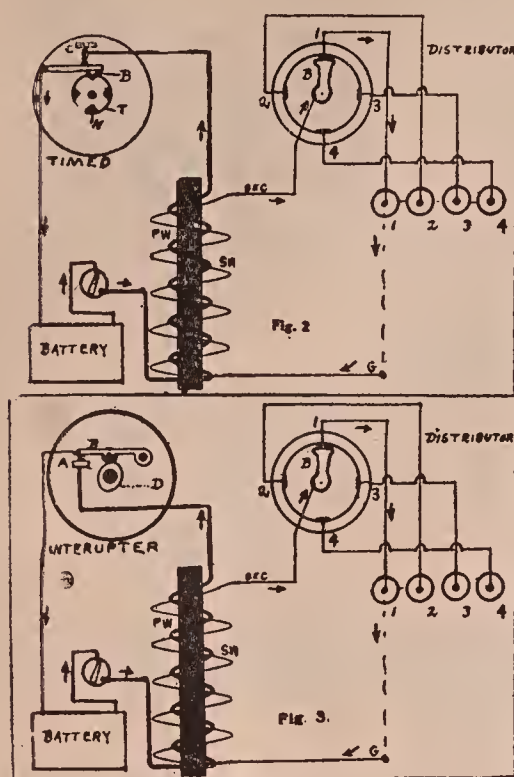
Diag. 74—A high tension distributor or synchronous system of ignition. P—primary winding. S—secondary. Note one end grounds to engine: usually grounded on the coil. VS—vibrator screw.
Fig. 2—Note distributor and commutator are together. The wiring diagram shows the two separated merely to explain the action.

clearly, the roller in the commutator makes contact with the segment, at the same time the vibrating points vibrate, which causes an induced current from the secondary winding; and the distributor brush at B is making contact with the segment in the distributor all at the same time.

The secondary distributor is made in combination with the commutator, each with as many contacts as the engine has cylinders, and the moving part of each attached to the same shaft that revolves. See figures 2 and 3 in diagram 74. The battery is connected to the single coil in the usual manner and runs from the primary winding of the coil to the segment on the commutator; from there to the roller through the metal of the engine over to the ground and returns back to the negative pole of the battery. Thus, when the commutator revolves and the roller makes contact with the segment, the current is passed through the one coil every time the contact is made. In a distributing system of this kind a wire is run from the secondary winding of the coil to the revolving or moving part of the distributor, and from there, when the distributor arm and brush makes contact with the segments, to which wires are fastened running to the spark plugs every time contact is made and the vibrator vibrates, the current flows from the secondary winding to the distributor and thus is distributed to the cylinders according to the firing order. The advantage of this system is that there is only one vibrator to keep in adjustment, and fewer parts; the disadvantage is that the coil has no rest, and the constant use tends to heat it, and destroy its insulation. The constant action of the vibrator is liable to burn the vibrating points and destroy them; therefore the modern ignition systems use a distributor system of a similar principle to the Delco and Atwater-Kent Systems. The vibrator is not used, the timer being of slightly different construction, which obviates the necessity of the vibrator.

Open and Closed Circuit Principle.—The modern interrupter or contact breaker, in its simplest terms means a mechanical switch which is driven by the engine

and is used to make and break the primary circuit at the time the spark is needed in the cylinder; or mechanical vibrators perform the same job that the trembler blade performs on the vibrating coil, and these mechanical vibrators are divided into two types; the vibrator in which the circuit of the primary winding of the coil is always open only when the arm, figure 2, diagram 75, is raised, contact is made with Tungsten Points screw, C. This closes the circuit, but it is suddenly opened again, and is known as the open circuit principle. Figure 3, diagram 75, the other type or system is that in which the circuit of the primary winding on coil is always closed. When the cam or interrupter D raises the arm B, the circuit is momentarily open, and suddenly closes again. This is called the closed circuit principle. The action interrupts the current or flow suddenly, hence, it is called an interrupter. Both of these systems have a mechanical method of making and breaking the primary circuit instead of the electrical method such as the vibrator; therefore, a coil without a vibrator is used and a single spark is given at the plug gap instead of a succession of sparks. Both the



Diag. # 75 Show the open and closed Circuit Mechanical Vibrators

open circuit and closed circuit systems accomplish the same purpose, which is to interrupt the flow of current in the primary winding in order to cause induced currents of high voltage to flow in the secondary winding, as previously explained. In the open circuit principle the contact must first be made before the current flow can be interrupted. This is made very rapidly, quicker than the eye can detect. In the closed circuit principle the current is flowing in the primary and is broken or interrupted by the contact points being separated by the cams which run at cam shaft speed. The closed circuit's advocates claim the advantage of perfect distributing of the high tension current to the cylinders, due to elimination of electrical and mechanical lag, whereas the open circuit advocates claim economy.

Electrical Lag means that the spark will not occur in the same position as regards piston travel at any and all engine speed. With a very high speed the piston might have a tendency to travel past the point of ignition before the open circuit timer made an open contact, whereas, with the closed circuit principle it merely opens the contact.

Mechanical Lag is eliminated much for the same reason, and the quicker and simpler the mechanism to interrupt the flow in the primary, the quicker the spark. For this reason some of the systems have been additionally improved by adding an automatic advance of the spark by a governor arrangement placed in the timer housing, so that the timer shaft will advance with the speed of the engine and cause the spark to occur as near the proper time as possible.

In diagram 75A the governor is illustrated at figures 6 and 7, and is mounted directly under the timer. One arm of the governor, G-1, is attached to the upper part of the timer shaft, which is free to advance with the action of the governor. The other arm of the governor automatically advances the time of the spark as the speed of the engine increases by centrifugal action of governor G W as shown. Note position of the ends of the timer shaft A retarded, figure 6, and advanced in figure 7.

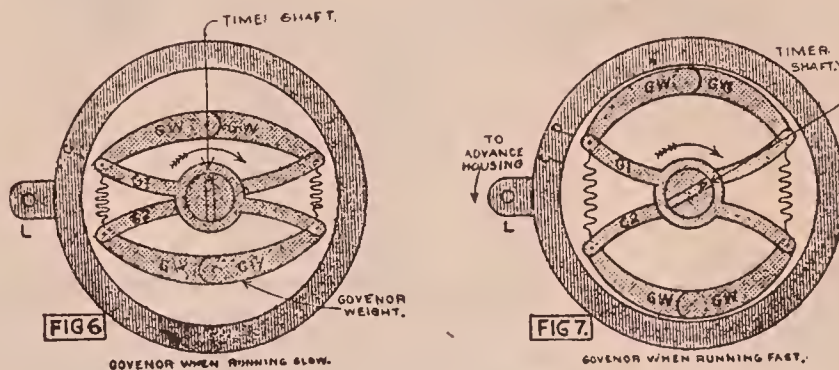
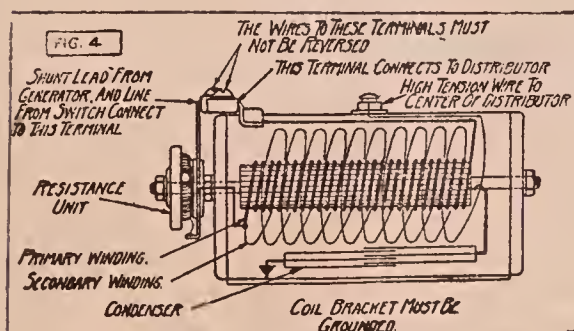


Diagram 75-A. Automatic Spark Control Governor.

The Resistant Unit—the Purpose.—When the closed circuit type of ignition is used, some method must be employed to disconnect the primary circuit if the switch is left on accidentally when the engine is not running. Resistant units and thermostats are therefore employed. The resistant unit used with the Delco System, which is an open circuit principle, is for the purpose of obtaining a more uniform current. It consists of a coil of resistance wire wound on a porcelain spool, as shown at diagram 76. Under ordinary conditions it remains cool and offers little resistance to the passage of current. If, for any reason, the ignition circuit remains closed for any considerable length of time, the current passing through the coil heats the resistant wire, increasing its resistance to a point where very little current passes, and insuring against a waste of current from the battery and damage to the ignition coil and timer contact. This insures uniform current through the primary winding.

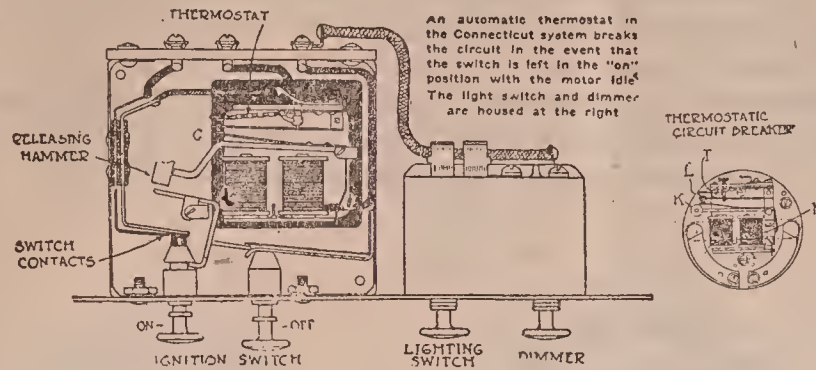


Diag. 76 The Resistant Unit

clapper in an electric bell. This arm strikes against a plate which releases whichever of the two buttons in the switch may be depressed or on. Thermostats may be said to act from thirty seconds to four minutes.

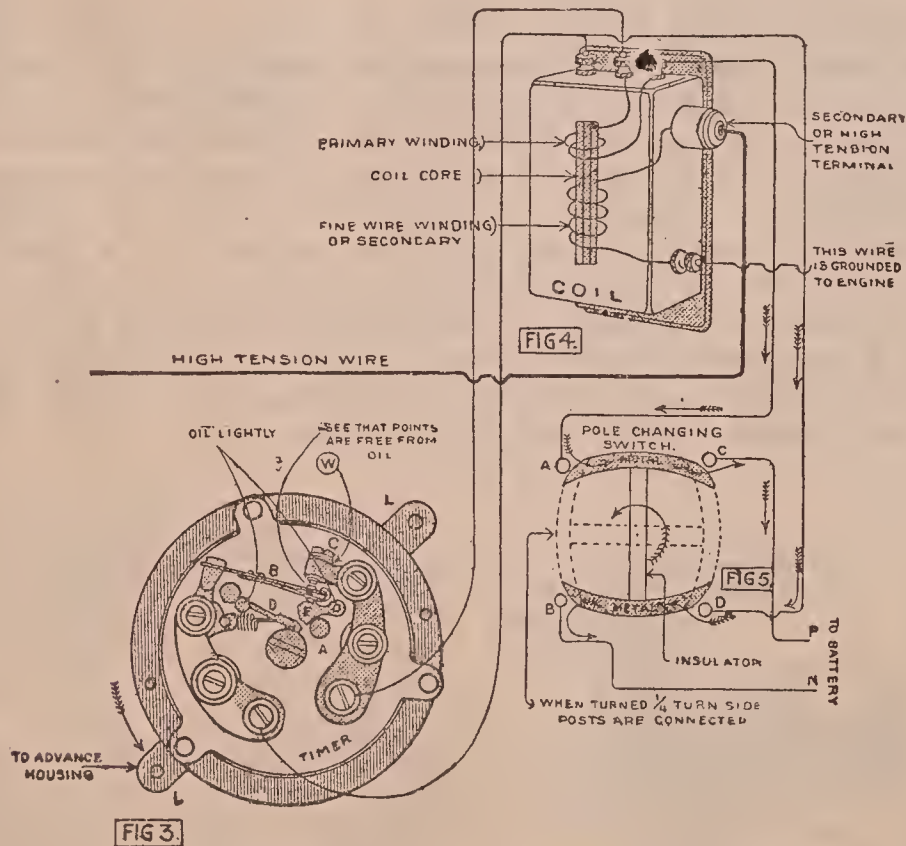
The Depolarizing Switch is also called a pole changing switch, used in connection with ignition systems; is provided for the purpose of keeping the contact point on timer

The Thermostat Circuit Breaker.—A thermostat circuit breaker mechanism is shown in diagram 77. The thermostat is inclosed within the ignition switch; its purpose is to open the circuit should the switch be left on when the engine is not running. The thermostat consists of a blade, T, which heats when the circuit passes through it from thirty seconds to four minutes without interruption, and is bent downward, making contact with contact L. This completes an electrical circuit which energizes the magnet M, causing the arm K to operate like the



Diag. 77 A Thermostat Circuit Breaker

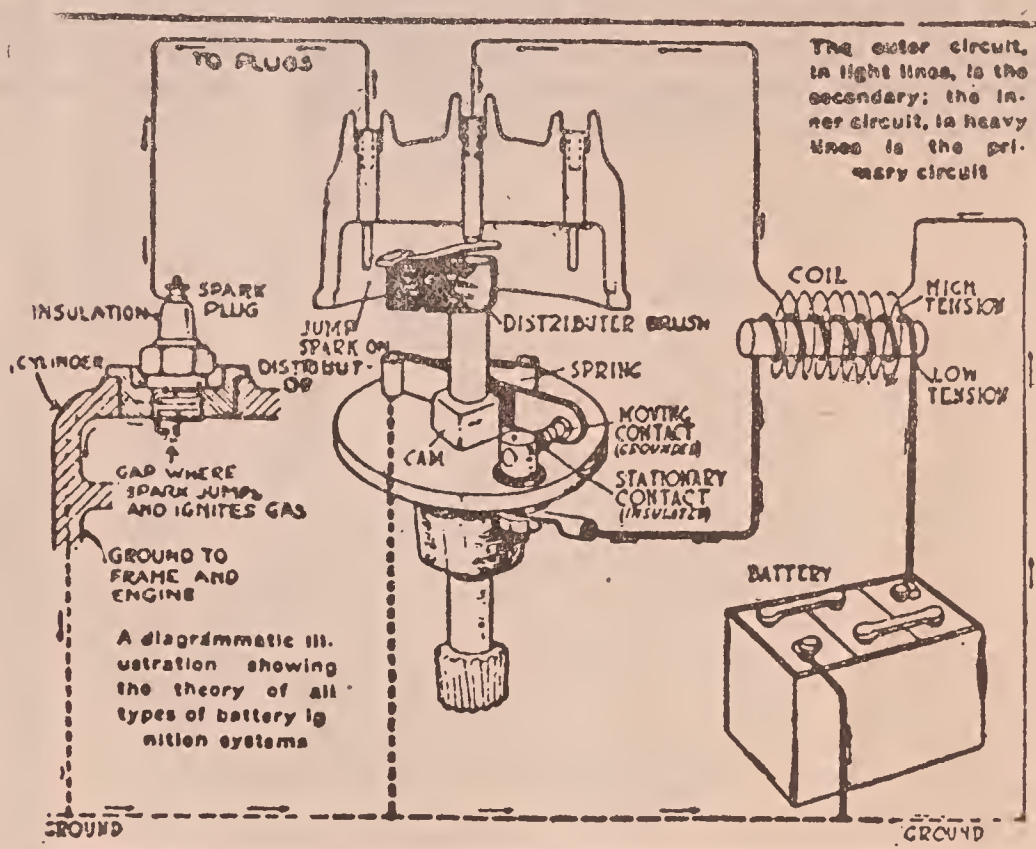
clean. When direct current is used, it has a tendency to burn and pit the points, whereas an alternating current is much easier on the points; therefore, to alternate the flow of current from N to S and S to N, or positive to negative and negative to positive, is the principle of this style switch. As already stated, direct current is used with all battery systems; therefore, a steady flow in one direction has a tendency to deposit the



Diag. 78 The Depolarizing Switch

metal from one point to the other, but by changing this flow of current occasionally the deposits will be put back to the other point again. This is similar to electroplating. Note the action of the polarity switch in diagram 78. The current, D, is now flowing negatively; A is flowing positively. By turning the switch one quarter turn the poles are changed; A will become negative and B will become positive. This change is made occasionally when running and has a tendency to keep contact points clean.

Parts of a Modern Battery and Coil System of Ignition.—The parts of this system consist of a storage battery, ignition coil, timer, distributor, spark plugs, and necessary wires to complete the circuit. Diagram 79 illustrates the theory upon which the battery ignition system is operated. The distributor is usually placed over the timer. First, note the timer shaft, which is driven from the cam shaft usually by a

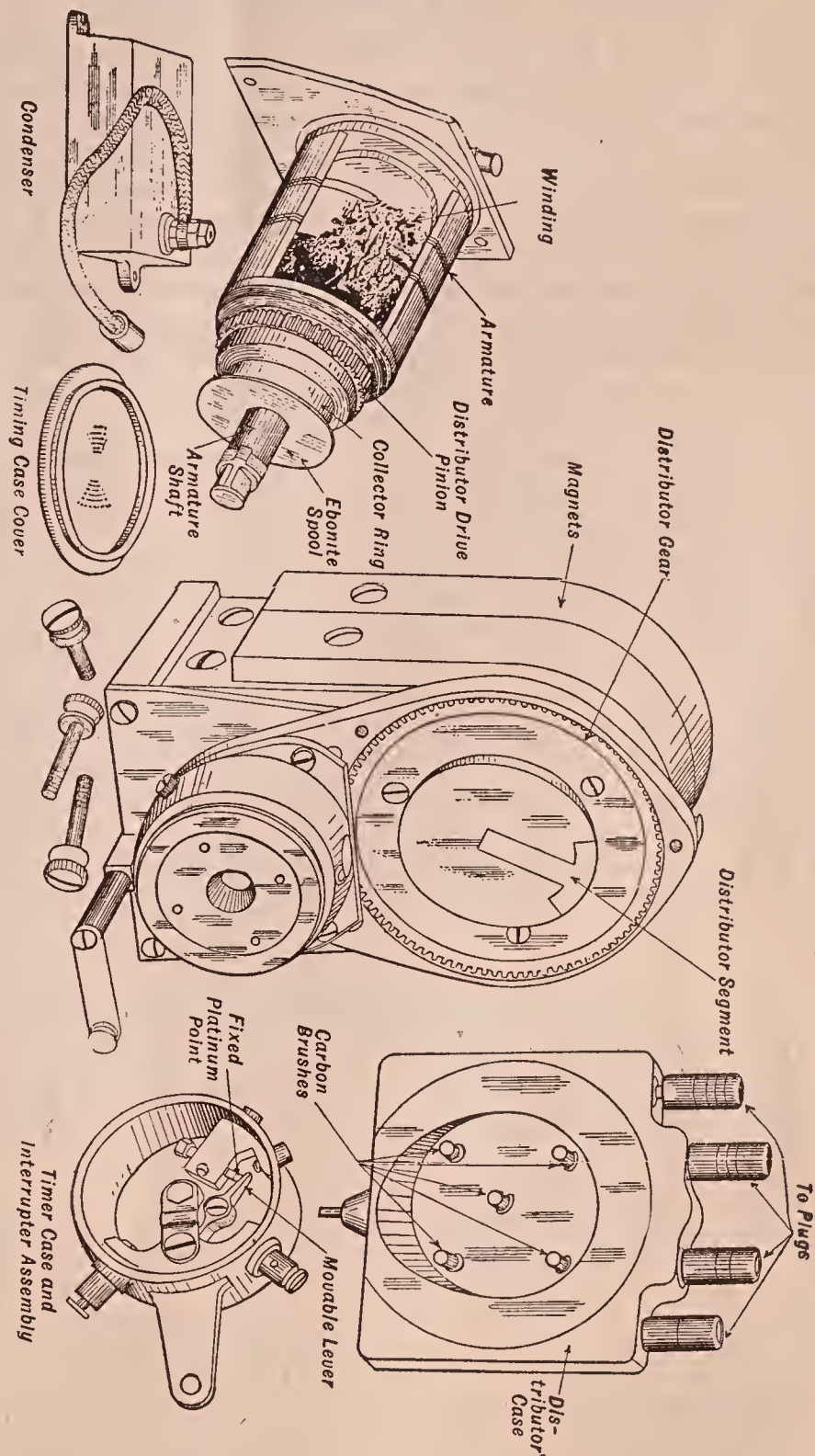


Diag. 79 Diagram illustrating the theory upon which battery ignition systems operate.

spiral tooth gear and at cam shaft speed. The distributor brush is connected to the upper end of this shaft and as it revolves makes contact with the spark plug terminals. Note center contact on gear of brush connecting with the secondary wire from the coil. The timer is that part containing the interrupter or contact breaker mechanism and is placed below the distributor.

This mechanism simply makes and then breaks the flow of current in the primary circuit. In this modern battery and coil system of ignition a primary current of six volts leaves the positive of the storage battery and flows up around the primary winding on the iron core, then over and across the breaker points or interrupter points, and then returns through the metal of the engine to the ground and back into the negative pole of the battery. This causes the iron core to become magnetized, which causes the secondary winding to be in a magnetic field. One end of the secondary winding runs over to the center of the distributor and fastens to a brush which is connected up to the distributor arm. The other end is either fastened to the primary winding or to a metal strip on the outside of the coil when the coil is installed you must be sure this metal terminal makes contact with the metal of the engine, so the high tension current will have a complete circuit. So remember A CURRENT OF ELECTRICITY MUST ALWAYS RETURN TO WHERE IT STARTS FROM. When the distributor arm is mak-

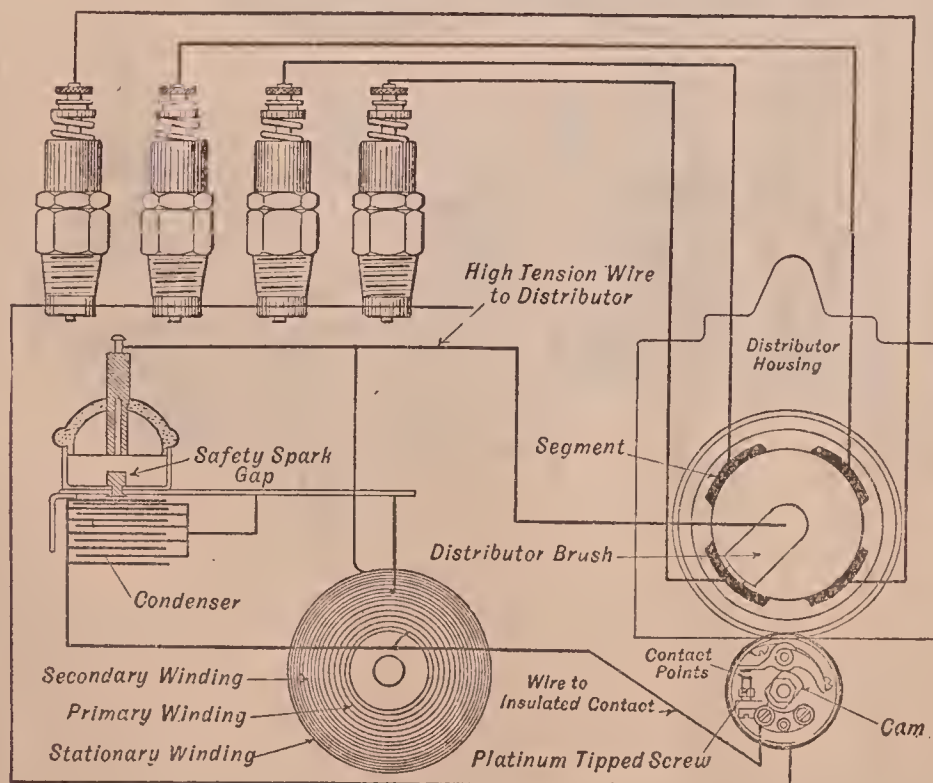
ing contact with a terminal or segment in the distributor housing it produces a complete circuit of the secondary winding, except the small gap in the spark plug, which is located in the combustion chamber. When the breaker points open or close suddenly it causes a change in the magnetic field, which causes an induced current of from ten to twenty thousand volts to arise in the secondary winding, and as one of the fundamental principles of electricity is that YOU HAVE ALWAYS GOT A COMPLETE CIRCUIT AS LONG AS THE VOLTAGE IS HIGH ENOUGH TO FORCE THE CURRENT THROUGH THE RESISTANCE; in this case the pressure of the current is greater than the resistance and therefore the current through the high tension circuit is completed, and, as passing through the gap in the spark plug, an arc is produced which is utilized to set the mixture in the engine cylinders on fire.



Diag. 80 Partially Dismantled Four-Cylinder Magneto, Showing Important Parts of Current-Producing and Distributing Elements.

CHAPTER 23. HIGH TENSION MAGNETOS.

The important parts of a four-cylinder form of high tension magneto are shown at Diagram 80, which is a view of a practically dismantled device. The armature assembly and one end of the end plates on which it is supported, are shown at the extreme left. Attached to the end of the armature shaft are the distributor driving pinion gear and the ebonite spool which carries the collector rings. The timer case and interrupter case and interrupter assembly are shown at the extreme right. Above it the distributor case is clearly shown. When the device is assembled the ends of the armature shaft protrude through the housing at the magnet assembly which is shown in the center of the group with the end plate which carries the distributor gear and disc and one end of the armature plate. The distributor gear serves to drive a hard rubber plate in which the distributor segments are embedded. When the distributor case is screwed in place, the carbon brushes which are spaced around the interior of the distributor case collect current from the revolving distributor segment and lead it to the spark plug by suitable cables which run from the terminal at the top of the distributor casing. There are two kinds of magnetos; one is termed the high tension system, in which a current of high voltage is delivered directly from the armature; the other is known as the low tension magneto. The current produced by the armature winding of the low tension magneto must be stepped-up, or increased in value before it is delivered to the spark plug, by an induction coil similar in construction to that needed in a battery ignition system. The high tension current is produced by means of a secondary winding on the armature itself and the whole apparatus is much more compact, and simpler to install than those which need a separate transformer coil. The simplified wiring system of a high tension magneto is shown at Diagram 81. The armature carries two windings, one indicated by the heavier lines at the bottom called the primary; the other composed of finer wire is known as the secondary. One end of the primary winding is grounded or fastened to the metal of the armature; the other is joined to the fixed contact screw of the



Diag. # 81 A simplified wiring system of a High Tension Magneto

contact breaker. This end is also joined to one end of the secondary winding, and the free end of the secondary winding is attached to the collecting ring carried by the ebonite spool. When the armature revolves between the pole pieces of the magnet an induced current will arise in the primary winding every time the polarity in the armature is changed, thus causing a primary current to flow around the primary winding. This current flowing around the primary winding causes the iron core to become a magnet which causes the secondary winding to be in a magnetic field. When the contact points separate, a current is induced in the secondary winding and is delivered to the center terminal of the distributor disc by the carbon brush which bears against the collecting ring. The various segments of the distributor are connected to the spark plug in the cylinder and every time the contact points separate a spark will be produced at one of the spark plugs because the revolving distributor brush will be in contact with one of the distributor segments when the contact breaker opens.

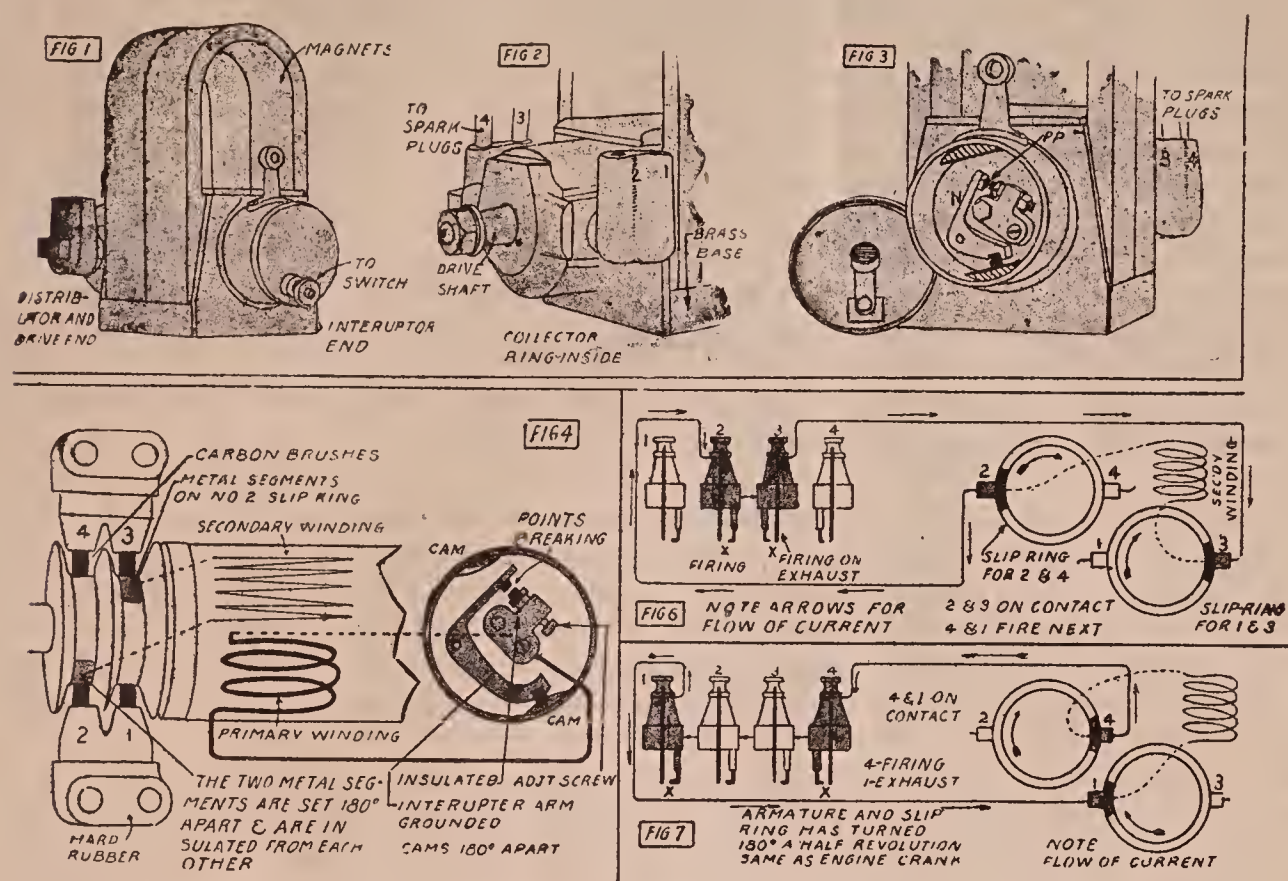
Safety Spark Gap Principle.—In Diagram 81 is illustrated the Safety Spark Gap. This is practically a safety valve for the high tension current. If, for example, a wire becomes detached from the spark plugs or from the distributor so that the ordinary path of high tension current was barred, there would be considerable danger of the current forcing a circuit through the insulation of the armature and thus doing very considerable damage, were it not given some easier escape as provided by the safety gap.

The Safety Spark Gap Construction.—It consists of a little chamber formed on top of the armature cover plate with a top of insulated material. The gap between the two terminals of the safety spark gap is longer than the gap between the spark plug, and ordinarily no spark will pass between these terminals; but if, owing to the conditions already mentioned, no spark can pass at the regular spark plug and the electromotive force in the secondary winding attains an abnormal value, a discharge will occur at the safety spark gap, thereby preventing the secondary current from rising still higher and burning out the windings.

Timing a Magneto Within Itself.—Timing a magneto within itself is to arrange the revolving distributor segment in the center of the carbon brush of the distributor case, then advance the spark half way, then without the distributor gear in mesh with the distributor drive pinion revolve the armature until breaker points are just ready to open; mesh the distributor drive pinion with the distributor gear and the magneto is in time with itself.

The Bosch NU4.—At diagram 82 the type NU4 Bosch magneto differs from the usual type of magneto in that the distinct gear driven distributor common to other types has been eliminated, and in its stead is a double slipring combining the function of current collector and distributor; otherwise it is about the same as any other form of magneto. The spark occurs in two cylinders at one time with this system, but one of the cylinders in which the spark occurs is on exhaust stroke; therefore the spark does no harm. The interrupter contact point in the full retarded position should open not later than top dead center of the compression stroke and the surplus spark always occur near the end of the exhaust stroke and never during the inlet stroke. In any four-cylinder, four-stroke cycle engine, regardless of firing order, when cylinder number 1 is nearing the end of compression stroke, cylinder number 4 is reaching the end of exhaust stroke, and vice versa.

Similar conditions apply also to cylinder numbers 2 and 3. Diagram 82 illustrates very clearly the different parts of the Bosch NU-4 and how they functionize. The brush when making contact with metal strip in collector ring, connects the high tension current and carries it to the spark plug. Note the connections from the ring to the plug. When brushes 2 and 3 are making contact, follow the circuit in figure 6 and note the arrow points. Now if the piston makes another stroke of 180 degrees travel, the arma-



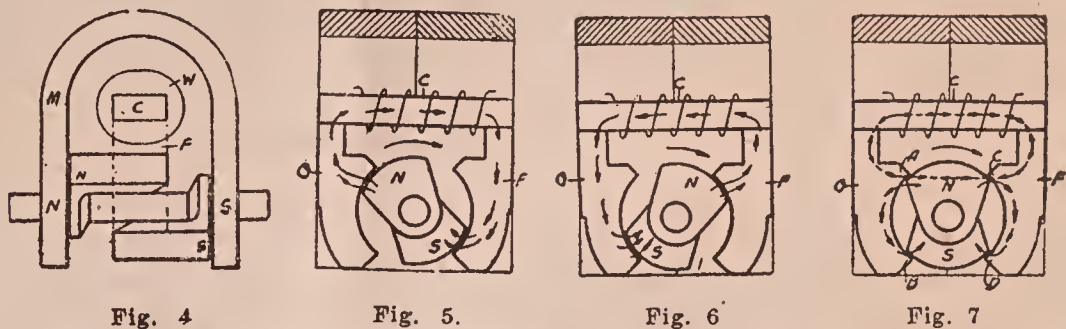
Diag. # 82 The Bosch NU4 type of High Tension Magneto
A two-point system

ture will turn 180, or half a revolution also, as it runs at engine speed in four-cylinder four-stroke cycle engine; therefore the contact or rings will turn 180 degrees or half a revolution and cylinders four and one will fire as in figure 7.

Timing the NU4 Magneto With Engine.—With the average engine the best result is obtained by connecting the magneto so that its interrupter housing is in full retarded position and the platinum interrupter screws or points are just about to separate when piston of number 1 cylinder is exactly on top dead center of the compression stroke; at the same time the metal of the slip ring should be in contact with the brush marked 1 in each of the brush holders, and this can be observed by removing one of the holders. The installation is complete by connecting one of the brushes marked 1 with cylinder number 1 and the others with cylinder number 4 and the two remaining brushes marked 2 and 3 with cylinder numbers 2 and 3. It is important to note that the type NU4, driven as it should be at engine speed, produces a surplus spark in each cylinder 360 degrees behind the effective or power spark, and in coupling the magneto to the engine it must be timed so that the surplus spark occurs during the exhaust stroke and not after the inlet valve has commenced to open.

CHAPTER 24. THE DIXIE HIGH TENSION MAGNETO.

The Mason Principle on Which the Dixon Operates is shown in diagram 83, figure 4. The magnets have two rotating polar extremities, N, S, which are always of the same polarity, never reversing. These poles are in practical contact with the inner cheeks of the permanent magnet M, all air gaps being eliminated; together with the U-shaped magnets they form a magnet with rotating ends positioned at right angles to the rotating poles or ends is a field constructor consisting of laminated pole pieces F and O, carrying across their top the laminated core C, carrying the winding W. When N is

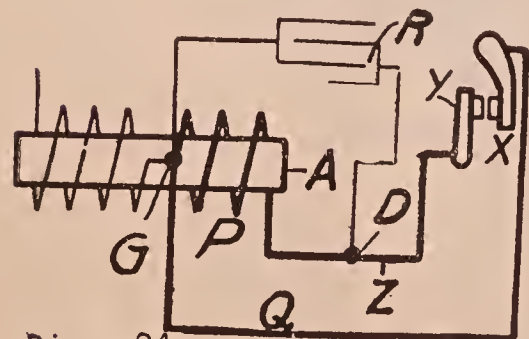


Diag. # 83 Dixie Induction type of High Tension Magneto, its principle of operation

opposite F the flux or magnetic lines of force flow through the core O to F; see figure 6. This action causes the laminated core with the winding wound on it to become magnetized, and as it revolves the polarity is changed, causing an induced current to appear in the primary winding, which flows out across the breaker points and back to where it started from. That causes the secondary winding to be in a magnetic field produced by the primary circuit, and when the breaker points break the primary circuit it causes the magnetic field to cease causing a high voltage current to appear in the secondary winding which is distributed to the spark plugs according to the way the engine fires.

Diagram 83 represents a rotating pole occupying a midway position between that shown in figures 5 and 6. Here the magnetic field pieces, F and O, are magnetically short circuited as if it were thereby completely cleaning all straying lines of force out of the core C.

Now the first great difference between the Dixie and the Armature type is in the fact that the rotating poles in the Dixie do not reverse their polarity at any time, consequently the lag due to the magnetic reluctance in this part is eliminated. This partly accounts for the high efficiency of the Dixie at high speed for multiple cylinder engines. In the Dixie the windings are actually never in the field. The line of force is shot through them and produces a snappy spark of peculiar and highly efficient igniting power owing to the quick break and absolute reverse of the flow of magnetic lines at each revolution. The Dixie rotating element consists of two pieces of cast iron with a piece of brass between them with no moving wire connections, brushes, laminations, condensers or other parts, just two pieces of iron.



Diag. 84 Simple primary circuit of Dixie No brushes or contacts except breaker points

In the Dixie the core of the coil, A, diagram 84, is stationary, and the inner end, G, of the primary winding, P, is grounded on the core. Q indicates the metal frame of the machine which is put together with screws so there are no brushes or sliding contacts. The condenser, R, in the Dixie is positioned immediately above the coil and is readily removable, it being only necessary to take out two screws. This condenser does not revolve as in the armature type. The terminals, D, are screwed on the head of the coil and the wires, Z, connect directly to the contact, Y, of the breaker; the breaker contacts in the Dixie

are stationary and do not revolve as the armature type. To adjust the contact points, X and Y, of the Dixie the points are readily adjusted while the magneto is running, therefore the intensity of the spark produced may be actually seen while the screws

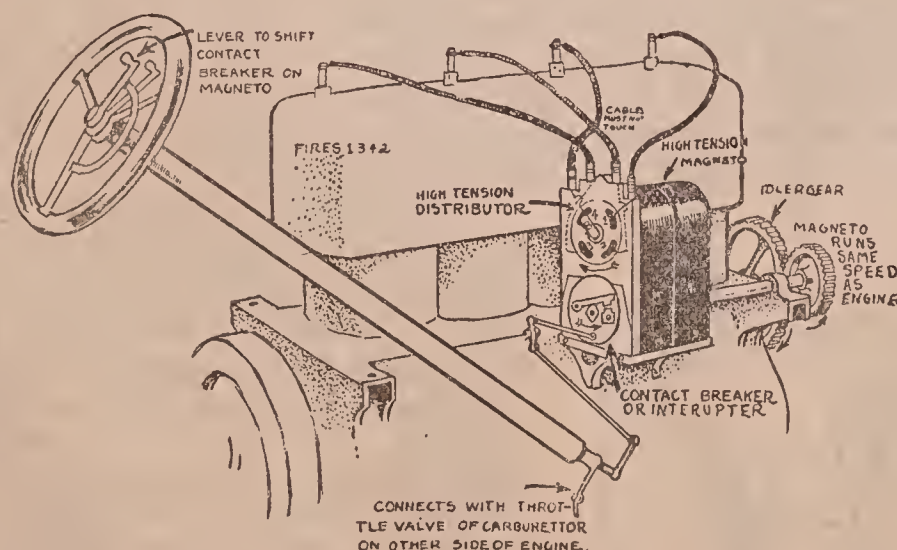
are being manipulated. The breaker point gap is set twenty thousandths of an inch or half way between a sixty-fourth and a thirty-second; and the spark plug gap twenty-five thousandths of an inch.

CHAPTER 25. MAGNETO DRIVING METHODS.

The magneto is usually placed along the side of the engine, mounted on a separate base provided for it. The base of the magneto is usually made of brass or aluminum, as brass or aluminum will not become magnetized; therefore, the magnetism is confined to the magnets; otherwise they would soon lose their magnetism. The magneto armature shaft is usually driven by gears, also silent chains. Loss, motion, and play should be eliminated in the magneto drive, and it is always advisable to drive the magneto through gears. The magneto may be driven by chains and sprocket if gears cannot be fitted, but the arrangement should be such that the chain will run with as little slack as possible, and at the same time not place undue side strain on the armature bearing. The necessity for preventing slipping prohibits driving the magneto by belt or by friction. On silent chain drives there is usually an idler or some means provided to take up the slack in the chain. The armature must be driven at a fixed speed because the armature must be in a vertical position, and interrupter points just breaking when the piston is in the correct position to receive the spark. In regular operation the correct position for the piston to receive the spark is just at the instant before it gets at the end of a compression stroke. Diagram 85 illustrates how the armature is therefore set by meshing the gears in relation to the gears on the crank shaft.

Means of Advancing and Retarding of Spark.—The meaning of advance of spark is to cause a spark to occur earlier before the piston is at the top of the compression stroke. The meaning of retard of spark is to cause spark to occur later on engines that are cranked by hand; the spark is usually set retarded after top, so that there will be no danger of a kick back.

Control of Spark.—As the spark occurs only when the primary circuit is broken by the opening or closing of the platinum contact points, the timing of the spark can

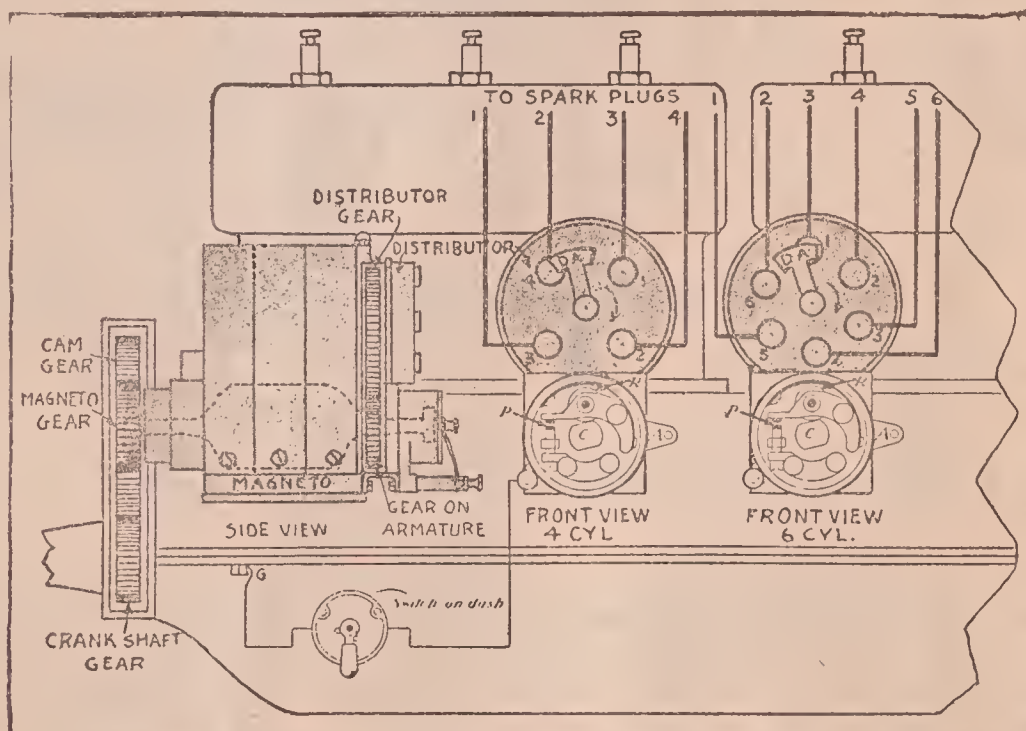


Diag. # 85 Shows how spark is controlled on Magneto

therefore be controlled by having these points to open sooner or later. This is accomplished by the annular movement of the timing lever. This movement is a timing arrangement of about 35 degrees. See Diagram 85. The spark is fully retarded when the timing lever, or sometimes called spark lever, is pushed as far as possible in the

direction of rotation of the armature and is advanced when pushed in the opposite direction. If cranking by hand, the spark must occur after the end of compression stroke, or else engine may kick back. If started by some form of self starter, it is then possible to start with slightly more advance than by starting by hand, because the self starter turns the engine crank faster.

Magneto Speed.—A high tension magneto of standard construction produces a high tension or jump spark current, this current being generated in the windings of the magneto without the use of a separate induction coil. Two ignition sparks are produced during each revolution of the armature in the usual type, and these are transmitted to the proper cylinders by means of the high tension distributor which is integral with the magneto. Once during each half revolution of the armature the primary circuit is broken and the abrupt interruption of the primary current results in the production of the high tension current in the secondary winding. The variation of ignition timing is effected on the magneto itself. The arrangement permits the interruption



Diag. 86 —Magneto Drive Methods. Magneto Armature Speed.

which is controlled by the spark lever as was explained in diagram 85 of the primary current to occur earlier or later in the revolution. On a four-cylinder engine four sparks are required during two revolutions of the crank shaft. The magneto gives two sparks or impulses to one revolution of the armature; therefore it would be geared to drive at the same speed as the crank shaft. See diagram 86.

On a six-cylinder engine six sparks are required during two revolutions of the crank shaft, therefore the armature would revolve one turn and half of another turn, making three sparks while the crank shaft made one turn; therefore, on two revolutions of the crank shaft the armature would make three revolutions, thus producing six sparks. The distributor, however, on both the four- and six-cylinder engines would revolve one half the speed of the crank shaft as the distributor arm would make one revolution to two revolutions of the crank shaft. By referring to diagram 86 note the cam C on the interrupter with projections 180 degrees, or one half of a revolution apart. This causes an interruption of current every half revolution of the armature.

CHAPTER 26. DRIVING METHODS OF DISTRIBUTOR AND TIMER IGNITION SYSTEMS.

In this system, shown at diagram 87, are combined the distribution and timer, together with ignition coil spark plugs, and wiring, all of which constitute the ignition system. The source of supply can be from storage battery, dry cells, or gen-

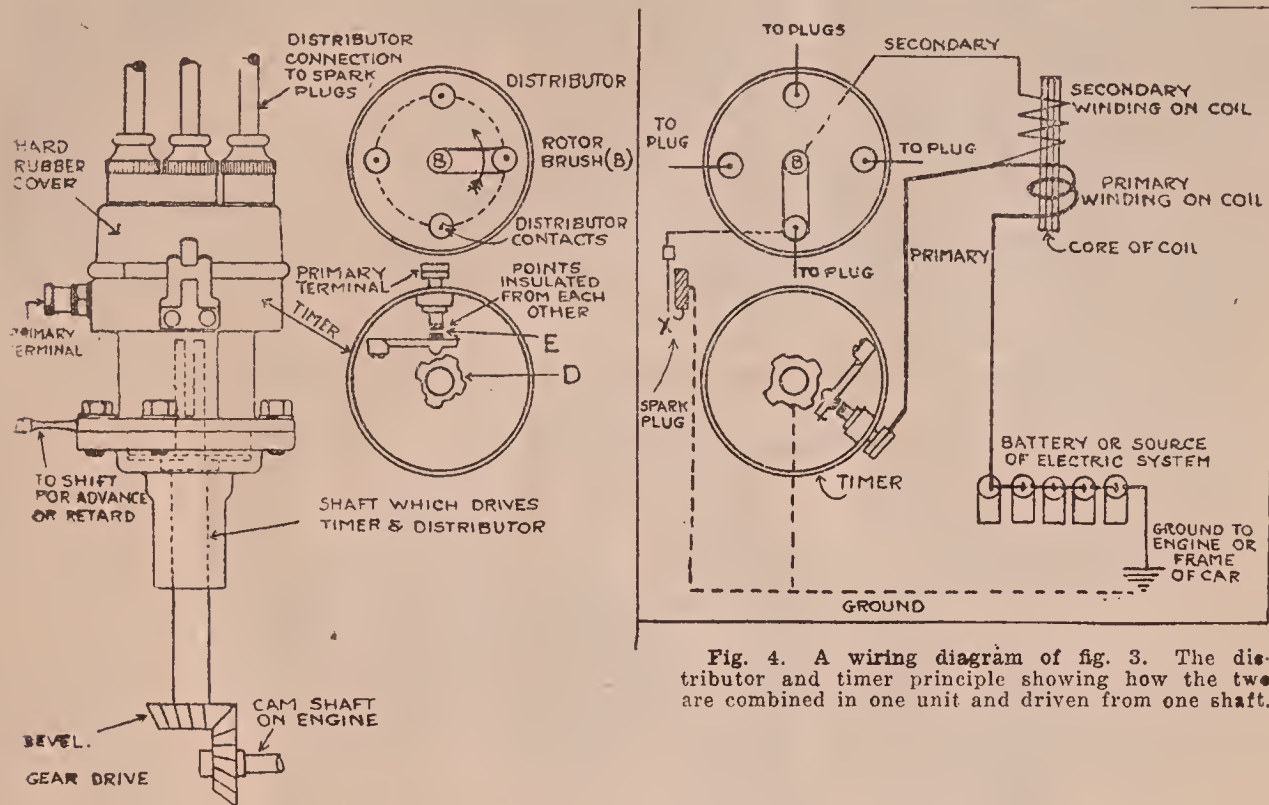


Fig. 4. A wiring diagram of fig. 3. The distributor and timer principle showing how the two are combined in one unit and driven from one shaft.

Diag. # 87 Driving methods of Distributor and Timer Ignition System

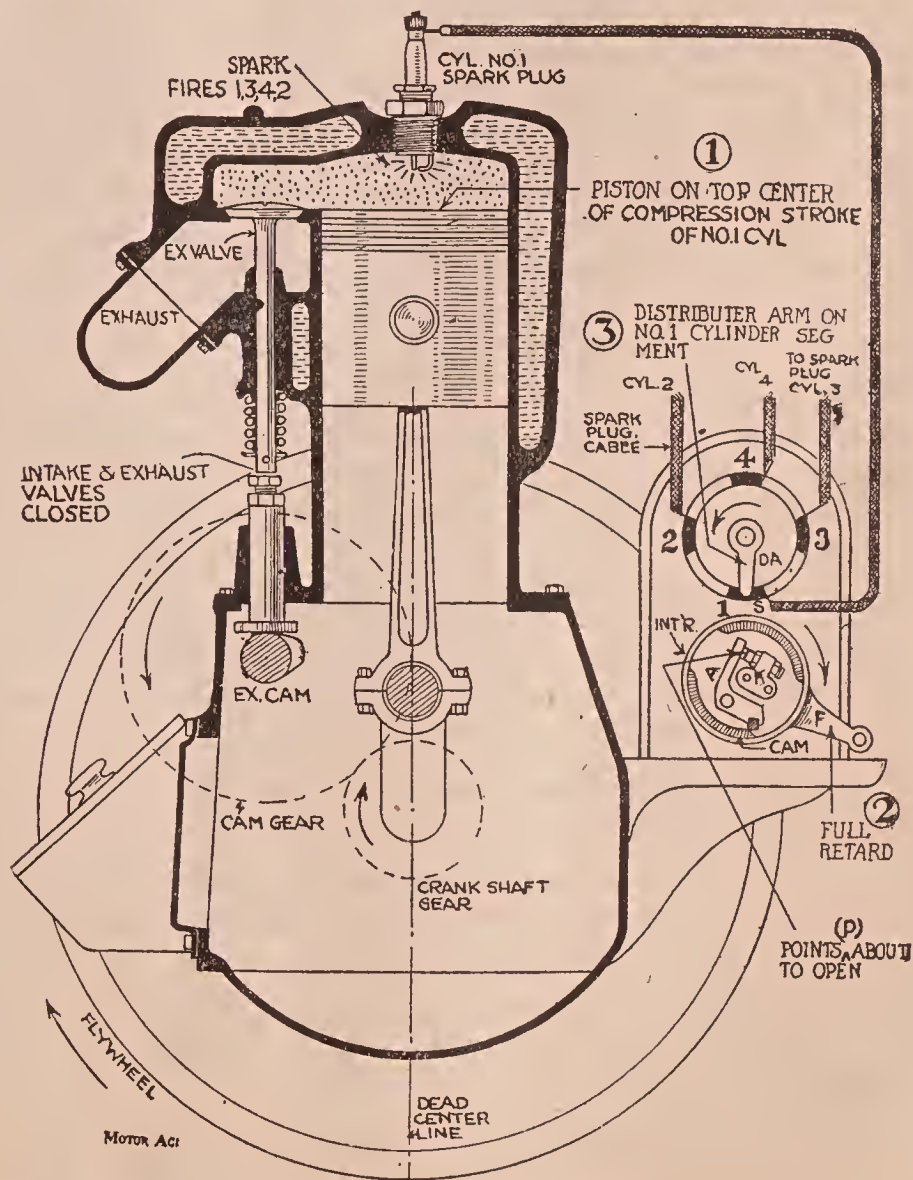
erator. The distributor and timer are mounted on the end of the shaft, while the other end carries a small beveled gear which meshes into a small gear on the cam shaft. Now it must be thoroughly understood that in a system of this kind where only one coil is used, and we have a distributor which is a mechanical switch, and is driven by the engine and is called upon to deliver the high tension current to the cylinders according to the firing order, and a timer, or breaker points which are called upon to either make or break the primary circuit at the time the spark is needed in the cylinder—now when these are being installed upon the engine they must be arranged to perform their duty at the right time. The interrupter points should just be breaking when the distributor arm is making contact with the segment, with the timer housing in a full retarded position, and the bevel gear on the end of the shaft which drives the timer and distributor must be connected with the gear on the cam shaft when the piston is at the end of the compression stroke, and as the interrupter points are just ready to break the circuit the gear should then be meshed. In timing any ignition system with an engine the means of controlling spark, and being able to have it occur at the right time, is accomplished by either making or breaking the primary circuit. This is accomplished by either making or breaking the primary circuit.

When a mechanical vibrator is used, as on a magneto, or in battery ignition system, the piston on number 1 cylinder should be put in firing position, or have the piston up as far as it will go, on compression stroke, then revolve the armature in the magneto, or turn shaft which drives timer and distributor with gear on lower end disengaged until the points are just opening with the interrupter housing in retarded position, then connect up the magneto with engine and magneto is in proper time with engine, or engage

gear on end of timer and distributor shaft and ignition is in time. On a Ford system where the vibrating coils are used, get number 1 cylinder in firing position, or on compression stroke, dead center, then with the timer housing in retarded position, arrange the roller which is fastened on the end of the cam shaft so it is just beginning to make contact with one of the segments in the timer case, and the ignition system is then in time.

CHAPTER 27. TIMING THE MAGNETO WITH THE ENGINE.

Diagram 88 illustrates very clearly how everything should be arranged; first, place number 1 piston on top of compression stroke. To do this on a four- or six-cylinder engine, turn the crank shaft the way it should revolve until the exhaust valve on number



Diag. 88 -Diagram showing how a high tension magneto is usually timed; interrupter housing (F) is retarded and piston is placed on top center of compression stroke.

4 or 6 cylinder opens and closes. This puts number 1 on compression stroke dead center. Second, retard the breaker box, also called interrupter housing, F, by turning it in the direction of the rotation of armature shaft as far as it will go. Third, turn armature in direction of rotation until the distributor arm, D A, is on segment S of number 1 spark plug cable connection; then turn armature one way or the other slightly until interrupter arm, A, is just starting to separate the platinum point connections P with K, which of course is caused by the cam action as shown. Fifth, couple magneto

connected. In this instance, by looking at the distributor connections and noting direction the distributor arm turns, the firing order would be 1-3-4-2. In some instances the piston is placed, say $\frac{1}{8}$ of an inch down after center of compression stroke, with breaker box retarded, then this would not permit advancing spark so far ahead of stroke. This is usually done on slow speed engines and where very slow running or idling is desired, as trucks and tractor engines. The armature turns in opposite direction to distributor; therefore always note direction distributor turns before connecting cables to plug. To tell how an engine fires watch the exhaust valve open and close in rotation, starting with number 1 cylinder.

CHAPTER 28 A DIGEST OF TROUBLES: CAUSE AND REMEDIES OF THE IGNITION SYSTEM.

Half the ability to make an adjustment or repair is the ability to discover its necessity. Always remember when diagnosing troubles, that there are three essentials necessary before an engine will run; first, gasoline; second, compression; third, spark. In dealing with engine trouble, always try and find out the possible cause of a trouble before starting to adjust something that does not need adjusting. An adjustment should never be changed without a knowledge of why the change is made, the effects the change should have, and how to restore the mechanism to its original adjustment. After you have gone carefully over the engine and find that the fuel system is operating properly, and that your compression is good, then you can look for the following ignition troubles.

Engine Fails to Start.—Lack of ignition current; if battery ignition, see if battery is too strong; remove one of the spark plug wires and hold it about three eighths of an inch away from the plug and terminal and see if the spark jumps the gap when the engine is cranked. Next, examine spark plugs. They may have become fouled from over-lubricating; or, if they have been considerably used, the points may be burned and corroded. If water has been splashed on the engine when it was hot, the porcelain of the plug may be cracked. See that the spark points are perfectly clean, and that the gap does not exceed one thirty-second of an inch for coil ignition, or one sixty-fourth of an inch for magneto ignition.

Engine Starts, but Misses.—This is generally caused from foul spark plugs, gap improperly adjusted, or from a weak coil.

Engine Runs Regularly for a Few Minutes and Then Stops.—Battery may be weak; ignition may be retarded too much; if there are two systems of ignition, try the other one.

Engine Stops Suddenly.—Loose wires; short circuit; loose wire connection; weak battery; points of interrupter may be closed by pitting; a sudden stop is almost always due to ignition trouble.

Engine Stops Slowly with Misfiring.—Battery exhausted; plugs foul through over-lubrication.

Engine Loops or Loads Up.—The spark may be set too far advanced; if this is the case, looping is likely to occur when spark is fully retarded; therefore, test the time of ignition.

Engine Misses Explosion.—Defective or dirty spark plugs. With the engine running idle, short circuit the spark plugs one at a time by touching a screw driver from the metal of the cylinder to the terminal of the plug; this prevents the plug from firing, and when one is short circuited that makes no difference in the running of the engine, you have probably located the plug at fault. If the spark plug wire is properly examined

and no loose connections or short circuits can be located, the trouble is the defective plug.

Engine Misses on High Speed.—Weak battery, if coil and battery ignition. If the engine misses at high speed but not on low or on a hard pull, then it is evident the spark plugs are O. K. The points on a magnetic or mechanical vibrator may need adjustment. A word of explanation on this. The engine may fire all right at low speed because the speed is slow enough, and the contact is long enough to allow the coil to build up. At high speed the contact is too short, consequently a slight turn of the contact screw is needed. The coil may be defective; that is, the vibrator points sticking. This is frequently the cause of missing or explosion. The points burn together. The cause of this is the direct current flowing in one direction continuously. Another cause is that of using too much pressure or voltage; for instance, coils are wound for six volts. If each dry cell gives $1\frac{1}{4}$ volts when working, and five cells are used, the coils points do very nicely. If, however, eight cells are used, the excess pressure is more than the condenser in coil can take care of; results, excessive sparking at platinum points on the vibrator and screw.

The contact points should be inspected occasionally to see that they are clean and flat, and also that the maximum gap between the points is according to the gauge on the special adjusting wrench, or about 12 to 14 thousandths or one sixty-fourth of an inch.

Engine Misses on Low Speed.—If magneto ignition the cause may be due to the slow speed of magneto, and weak current generated. Try advancing the spark more; also examine the interrupter points; examine spark plug points; if missing still occurs, then there are two other points to consider, loose connections or a broken down coil. A spark plug may be foul; it has been known that a bad plug will not cause missing at all speeds.

Engine Misses at All Speeds.—Defective spark plugs, loose connections, weak battery, loose switch parts, broken wire, slight short circuit.

Engine Does Not Deliver Full Power.—Timing of ignition may be wrong. Set too far retarded or too far advanced, weak ignition, defects in distributor.

Engine Overheats.—Running on retarded spark invariably causes heating. The spark lever should be raised up or advanced as far as possible at all times without causing the engine to knock.

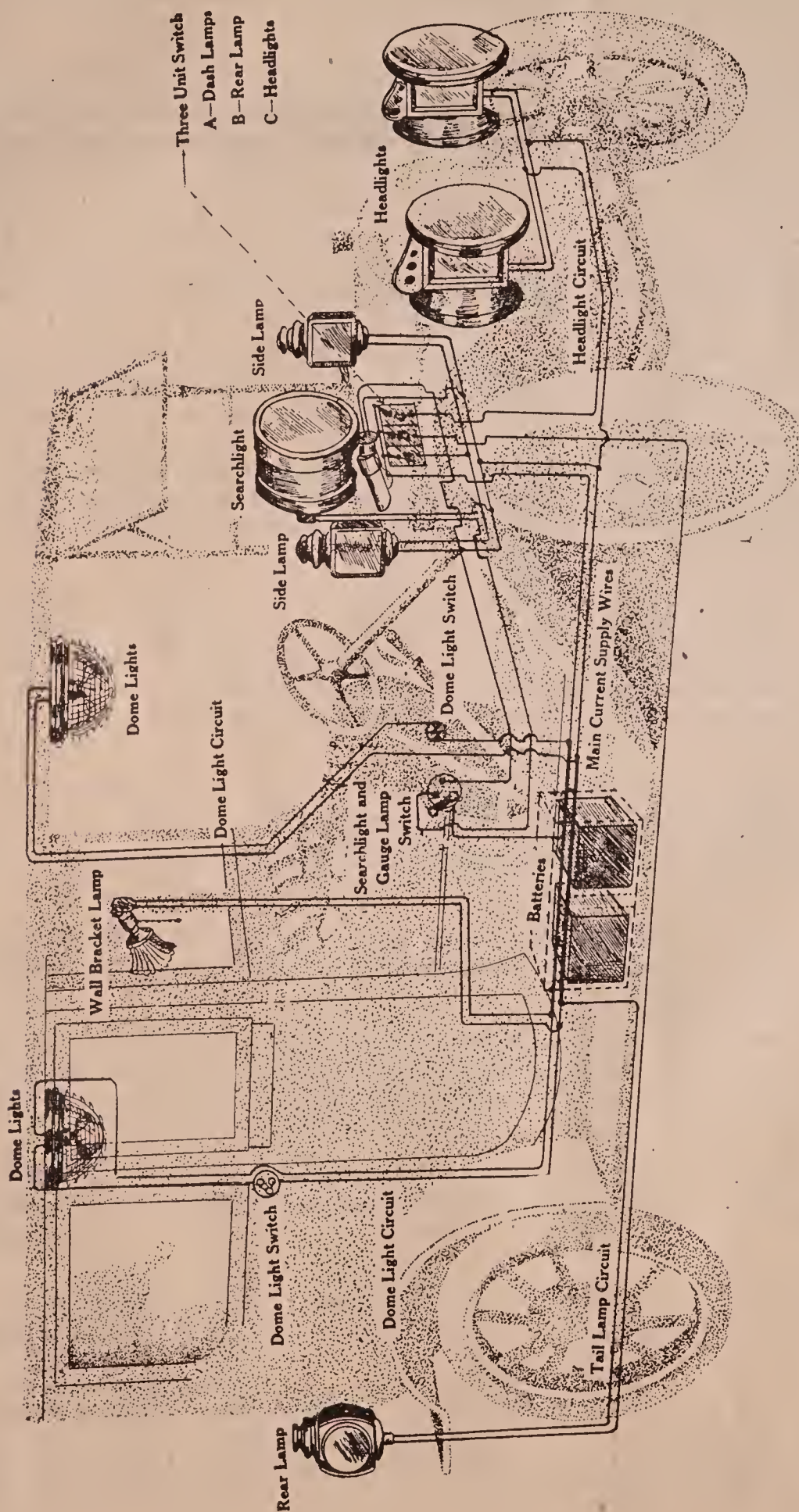
Engine Knocks.—The most common knock is the ignition knock, caused by too much advance of spark. This causes the mixture to be set on fire too early, causing the gas to be set on fire, and the pressure from the explosion forces the piston back instead of letting it get past top dead center and forcing it down on power stroke.

Engine Will Not Stop When Switched Off.—If firing is regular, the switch is defective. If firing is irregular, pre-ignition is the cause, caused by poor oil or carbon deposits in the combustion chamber which harden and become red hot, hence resulting in preignition.

Engine Back Fires in Muffler.—Usually caused when coasting with spark off and retarded, suddenly throwing on the switch, thereby firing charges and which have entered muffler unfired.

Overheating of Exhaust Pipe and Muffler.—Very late ignition will not give enough time to permit the charge to burn before the exhaust valve opens.

Engine Makes an Unusual Hissing Noise.—Spark plug porcelain broken; spark plugs not tightly screwed into cylinder.



Diag. # 89 Show a Motor Car completely lighted with Electricity

CHAPTER 29. LIGHTING THE MOTOR CAR BY ELECTRICITY.

Electricity has many advantages as a lighting medium, and all those which make it so desirable for domestic use are supplemented by other features which specially adapt it to motor car service. The convenience and cleanliness of the lamps, the fact that the light is not affected by the speed, character of the road surface, or wind, and that it remains of uniform brilliancy as long as current of proper strength is supplied, are some of its advantages. The ease with which the lights may be turned on or off by merely operating a switch or pressing a button is a feature of merit, and that no skill is required to obtain proper results makes the electric current entirely suitable as an illuminating agent for motor cars. Diagram 89 shows a motor car fully equipped lighting system with a chemical generator for current production. The wiring is very simple. The current flows from one wire of the positive main current supply wire out to the switch; when the switch is closed it flows on and through the light and returns to where it started from. It does the same when all the circuits are closed by the different switches. When the storage battery runs down it must be charged from some outside source. The most important component of modern lighting systems is the incandescent light in which a conductor or filament is heated because it offers a high resistance to the passage of electric current. To prevent a rapid oxidation or burning away of the incandescent conductor it is placed in a glass globe from which practically all air has been taken out by an air pump; this forming the familiar incandescent bulb of commerce.



Diag. 90 The incandescent lamp

As the filament is heated by the current flow, no air is needed to maintain combustion, as is necessary when inflammable substances are burned to obtain light. The normal life of an incandescent lamp filament is from one thousand to two thousand working hours. This filament is made of carbonizing a special form of cotton thread; the ends of the carbonized thread are attached to platinum wire which are sealed into the glass balls of the bulb and which make contact, one with the base or socket, and the other with its rim, these being the electrodes through which the current enters and leaves the lamp as shown in Diagram 90.

At Diagram 91 instead of taking off the storage battery or charging it from some outside source, we have a dynamo connected up with the engine which produces a direct current suitable to keep the storage battery charged. You will observe four switches at diagram 91. Number 1 switch is in the circuit between the dynamo and storage battery; it is called a cut-out relay or magnetic switch.

CHAPTER 30. CUT OUT RELAY.

Diagram 92 illustrates an automatic cut out switch A. As shown it is placed in the circuit between the generator and storage battery. This device automatically connects the generator to the lighting system and battery when the engine is running at say approximately seven to ten miles per hour, car speed or over, and charges the battery and supplies current for lights and ignition. When running at less speed the switch disconnects the generator from the battery and lighting circuit, and the battery then is called upon to supply the current. The principle of the cut out relay is very simple, and easy to understand. When the engine is not running the platinum points at V3, diagram 92, are open, and if the lights are needed the current must be supplied from the battery. The spring V2 keeps the points separated so the storage battery cannot discharge through the generator and soon exhaust battery. When the engine is started, the generator, which is connected with the engine, begins to generate as soon as the engine gets to making three or four hundred revolutions per minute or more; a current of sufficient strength is generated and flows out and around the shunt circuit and wind-

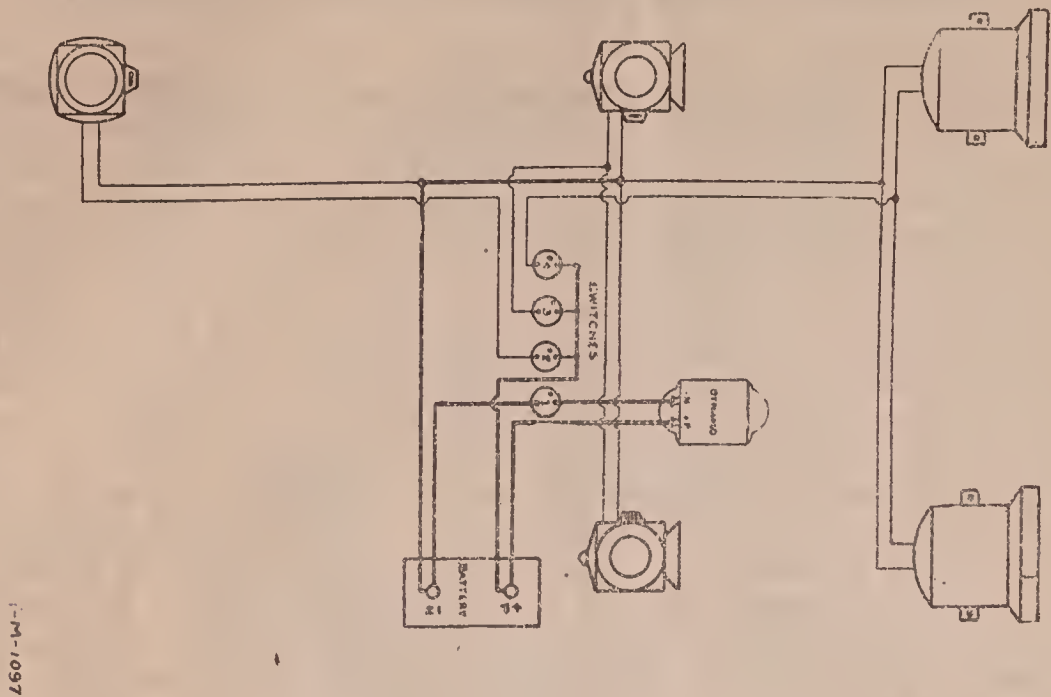


Diagram 91 Wiring Diagram of Lighting Dynamo, Outlining the Connections of Generator, Storage Battery and Switches.

ing at P, which is wound around the iron core, which causes it to become an electro-magnet and remains a magnet as long as the current flows from the generator. Thus the iron core becomes a magnet and it attracts the blade V1 and draws it towards it. This closes the points V3, and allows the main current to flow from generator up to the

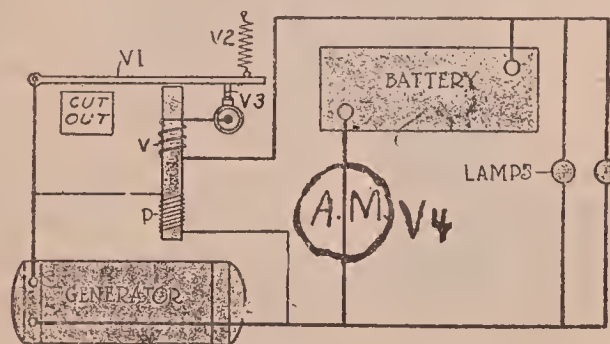


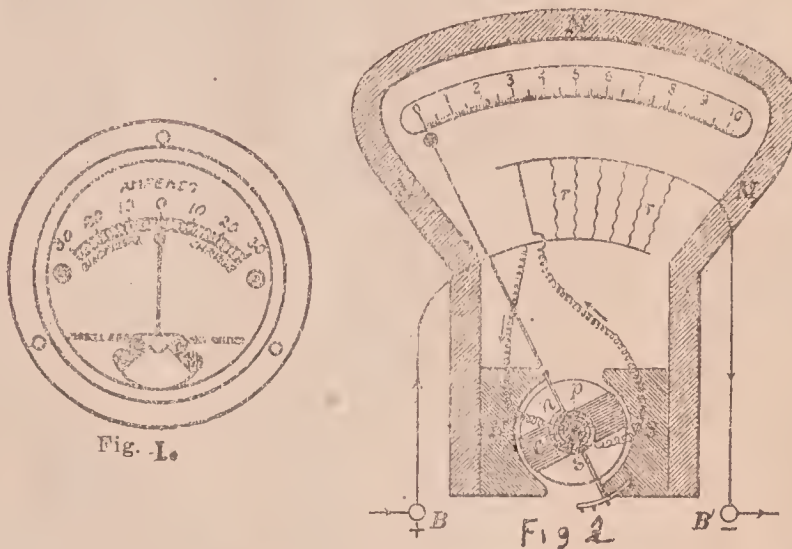
Diagram 92 The automatic magnetic cut out, opens the circuit between battery and generator when the generator is running slow or engine is stopped, also referred to as the "vibrator type" of cut out.

trembler blade V1, across the points at V3 and around the winding at V and over to storage battery and lights and returns to where it started. As soon as the generator stops putting out a current and no current flows around the windings on the iron core it ceases to be a magnet. The spring V2 holds the blade V1 away from the iron core, thus separating the points at V3, thus opening the circuit between battery and generator.

CHAPTER 31. THE AMPERE METER.

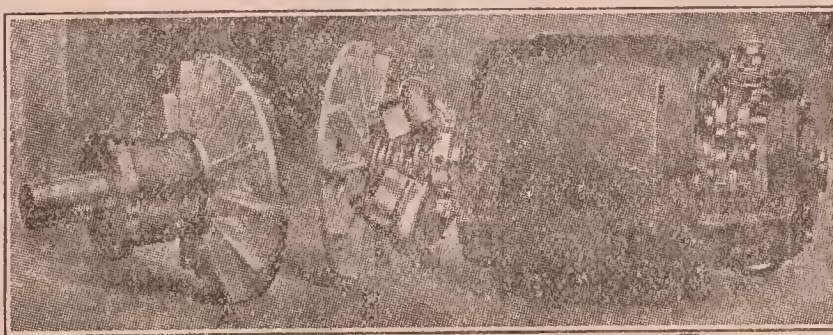
Purpose of Ampere Meter.—It is provided as a signal for the operator; it indicates when the dynamo charges battery and at what rate, as shown in figure 1, diagram 93. It also indicates the rate of discharge from battery to lamps; it shows whether or not the system is working properly. When the battery is neither charging nor discharging the pointers should indicate 0. The ammeter is placed in series with the circuit as shown in diagram 92 at V4.

The Principle and Construction of the Commercial Ammeter and Volt Meter is shown at figure 2, diagram 93. The coil C is pivoted on jewel bearings and is held at its zero position by a spiral spring, P. When a current flows through the instrument, were it not for the spring, P, the coil would turn through about 120 degrees or until its north



Diag. # 93, Construction of the Commercial Ammeter

pole came opposite the south pole of the magnet. This zero position of the coil is chosen because it enables the scale divisions to be nearly equal. The shunt coil, R, is of practically negligible resistance. The volt meter differs from the ammeter only in that the coil, R, is in series with C and is of high resistance. The same instrument may have its range changed or may even be used interchangeably as an ammeter or a volt meter by suitably changing the coil, R.

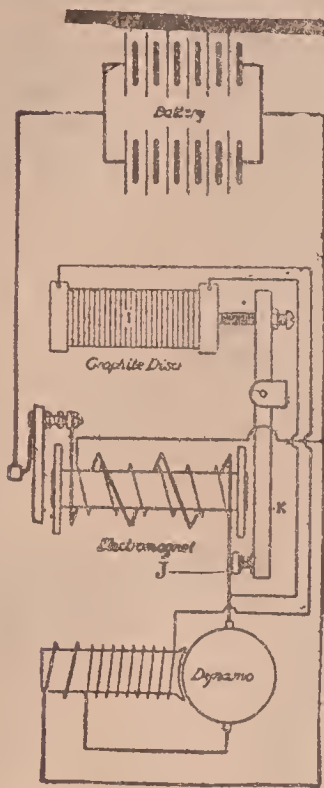


Diag. # 94 Shows the simplicity of the friction clutch and governor parts

CHAPTER 32. REGULATION OF OUTPUT OF GENERATOR.

In a dynamo the voltage increases with speed. The dynamo begins to charge the battery at about seven to ten miles per hour, but it is also desirable to charge a battery and supply current for lights at a higher speed. As the voltage increases with

the speed then the lights would be burnt out, and generator would be injured by excessive sparking at commutator, and an excessive amount of current would flow to the battery; therefore, some form of regulation must be used to keep the voltage or quantity of current constant at a high speed. We will first illustrate and discuss a mechanical governor which controls the speed of the armature to a fixed number of revolutions.

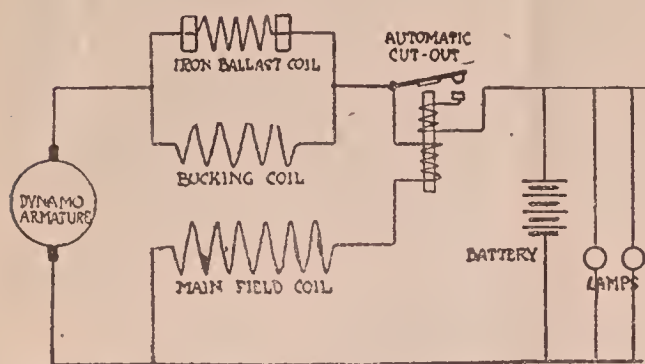


Diag. # 95. The Graphite Disc Regulator

Diagram 94 illustrates a generator with a mechanical governor. The regulation of the maximum output is affected by the centrifugal governor at C and C, which keeps the speed of the machine constant. The variations in speed are taken care of by the automatic clutch. The clutch, A and B, will slip more or less according to the speed of the engine, and the amount of such slippage is controlled by the governor, C C. As soon as the speed of the armature increases beyond the rated number of revolutions, the governor at C C will act on the friction clutch at A and B; in other words, the two clutch halves, A and B, will be pulled apart and slip in such a manner that the armature will rotate not faster than the predetermined speed.

The Graphite Disc Regulation of Constant Voltage.—The regulation of constant voltage is maintained by pressure upon the graphite disc as shown at diagram 95, which are pressed together by the lever K, by pressure of coil spring J; the less the pressure the greater the resistance thrown into the field winding; for if the discs are not close and tight, resistance is offered to flow of current; note the pressure upon these discs is also controlled by the electro magnet. The stronger the current flow from the generator, the greater will be the magnetic pull on K, and J; thereby taking pressure off the graphite disc they separate offering a resistance which cuts down the current going around the field cores, thus cutting down the magnetic field produced in the generator and therefore causing the current output from the generator to be constant at all speeds.

The Thermal Principle of Control.—At diagram 96, the action is to reduce the strength of the field magnets at high speed by means of a counter excitation produced by a few turns of magnetic wire called a bucking coil on the field pole, figure 2, diagram 96. The amount of current passing through the bucking coil is determined automatically by the varying resistance of a small core of iron wire called the ballast coil, figure 3, diagram 96, which is made in the form of a cartridge fuse, and is carried in clips on the switchboard in the main line between the dynamo and the battery. At low dynamo speed and output of current, this ballast coil is cold and acts as a short circuit to divert the current from the field bucking coil. As the output increases, the iron wire becomes heated, although its resistance remains practically the same as when cold, until reaching a certain critical temperature just below the dull red heat. Its resistance goes up with a jump so that practically speaking it will not permit another ampere to pass and after that the excess current must pass through the field bucking coil. At car speed below fifteen miles an hour the dynamo acts as a simple, uncontrolled, shunt-wound machine, while at the higher speeds, owing to the counter-effect of the bucking coil, the resultant excitation is barely one sixth of the excitation due to the main shunt field coil alone. In order to keep the current in the main shunt field coil as nearly constant as possible, it is connected at a point below the ballast coil, figure 2, instead of directly across the brushes;



Diag. 96—Diagram of Rushmore generating system. The bucking coil is a "series" winding on the field. The main field winding is "shunted" across. Cut-out is the usual magnetic type.

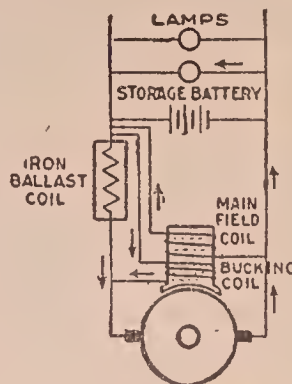


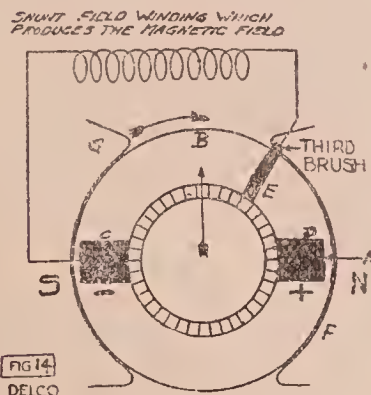
Fig. 2.—Diagram showing the main field winding and bucking coil series winding and location of "ballast coil" in circuit.



Fig. 3.—The "Iron wire" "thermal" type regulator of current, called "ballast coil" which allows a certain quantity of current to pass, but beyond that quantity the iron wire heats and offers resistance to flow of current in field, therefore the current must go through the bucking coil or series winding (in figs. 1 & 2) which action does not permit the current to increase but keeps it at a constant strength.

thus it does not feel the fluctuation of voltage at the brushes. The ballast coil which allows a certain quantity of current to pass, but beyond that quantity the iron wire heats and offers resistance to the flow of current in the field; therefore the current must go through the bucking coils or series winding in figures 1 and 2, which action does not permit the current to increase, but keeps it at a constant strain.

Third Brush Regulation.—In diagram 97 the regulation of the generator is affected by what is known as a third brush excitation. From the foregoing explanations of the generating of electricity, and from the fact that the voltage generated varies directly with the speed, it is evident in order to maintain a nearly constant voltage with a variable speed it becomes necessary to decrease the magnetic field, as the speed increases. Since the magnetic field of the generator is produced by the current in the shunt field windings, it is evident that should the shunt field current decrease, as the speed of the engine increases, the regulation would be affected. In order to fully understand this explanation it must be borne in mind that a current of electricity always has a magnetic effect, whether this is desirable or not. Referring to diagram 97, the theory of this regulation is as follows; the full voltage of the generator is obtained from the large brushes, marked C and D. When the magnetic field from the pole pieces, N and S, is not disturbed by any other influence, each coil is generating uni-



Diag. # 97
The third brush regulation

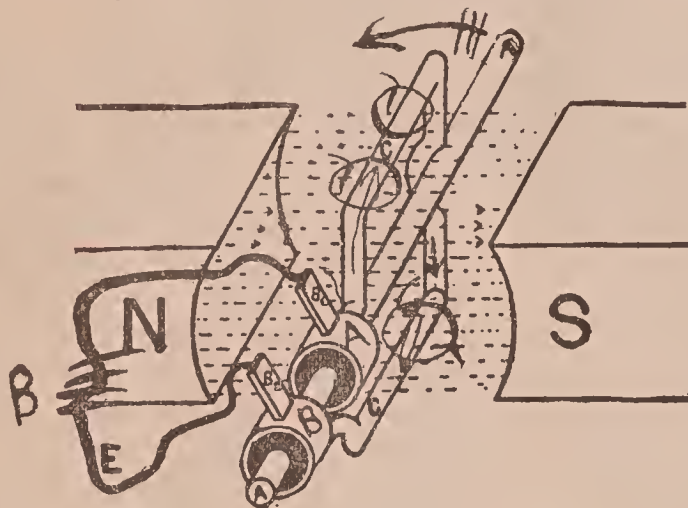
formly as it passes under the pole pieces. The voltage from the commutator bar to the next one gradually increases from zero to full voltage, depending on position of coils to which the commutator bar is attached. The voltage from the brush, C, is about five volts when the total voltage from the brush C to brush D is six and one half volts, and five volts is applied to the shunt field winder. This five volts is sufficient to cause approximately $1\frac{1}{4}$ ampères to flow in the shunt field winding. As the speed of the generator is increased the voltage is increased, causing the current to charge the storage battery and supply the lights.

The charging current flows through the armature windings producing a magnetic effect in the direction of the arrow B. This magnetic effect acts upon the main magnetic

field, which is in the direction of the arrow, A, with the result that the magnetic field is twisted out of its original position in very much the same manner as two streams of water coming together are each deflected from their original position. This deflection causes the magnetic field to be strong at the pole tips, marked G and F, and weak at the opposite pole tips, with the result that the coil generates a very low voltage while passing from the brush E to the brush D; the coils at this time are under the pole tips having a weak field and generate a greater part of their voltage while passing from the brush, C, to E. The amount of this variation depends upon the speed that the generator is driven, with the result that the shunt field current decreases as the speed increases. The third brush, E, is adjustable. Moving this brush in direction of rotation increases the charging rate to battery; moving brush in opposite direction decreases the charging rate.

CHAPTER 33. THE ELECTRIC MOTOR.

In construction the electric motor differs in no essential respect from the dynamo. Diagram 98 illustrates the principle of the electric motor. A current from an outside source flows from A through the conductor in one direction on one side, and in the



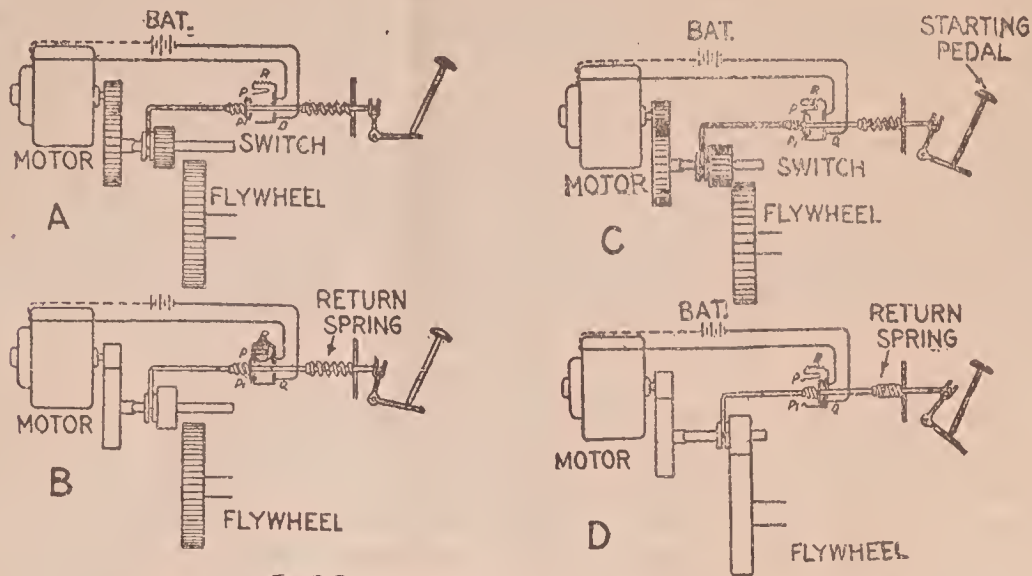
Diag. # 98 Show a simple
Electrical Motor

opposite direction on the other side. Remember that when a current flows over a wire from you there are always circular fields of magnetism flowing clockwise around the wire. Now the motor rule is stated thus: A current in a magnetic field tends to move away from the side on which its lines are added to those of the field; therefore, the conductor on the top is urged downward by the influence of the field, and the conductor in the bottom is urged upward. The armature will therefore begin to rotate, and this rotation will continue as long as the current is sent in at A and comes out at B. To reverse the motion all that is necessary is to arrange the current to flow in at B and out at A, while the magnetic field remains unchanged.

The Application of the Electric Starting Motor to the Engine.—The starting motor can drive the gasoline engine through the fly wheel or by connection with the crank shaft, or drive through the transmission shaft. The drive through the fly wheel is the most popular.

Mechanical Gear Shift.—The action of the starting switch with the mechanical gear shift in diagram 99 illustrates very clearly its principle. The contact making parts of the switch are shown mounted directly on the gear shift drive, though it can be mounted on any rod interconnected with the gear shift rod. At A is shown the off-position of the short pinion and switch contractor. Pressure on the starting lever moves the shift rod, first to the position B, closing the motor circuit at P and P, through

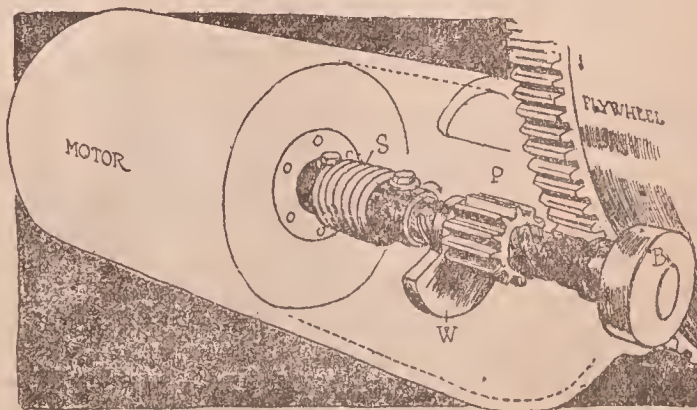
the resistance R; this starts the motor at a low speed. Further motion on the shift rod to position C opens the electric circuit. The motor and pinion continue to turn, owing to



Diag. # 99 Show the Mechanical Gear Shift.

their momentum. When position C is reached the pinion is still turning slow, so that it cannot fail to mesh with the gear; but, as the power is turned off the motor, there is no difficulty in sliding the teeth into full engagement. As soon as the teeth do engage the pressure on the starting lever shifts the rod to position D, closing the electric circuit at Q. After the pinion and gear has meshed a sufficient distance to present a good bearing length on the teeth, this connects the motor directly on the storage battery so that full power is developed, and it turns the engine over until the starting lever is released. When the pressure is removed from the starting lever, a spring returns the shift rod and all parts to position A. This releases the gears and opens the electric circuit and the motor comes to rest.

The Bendix Automatic Gear Shifting Pinion.—This type is used on a majority of cars to-day. The gear ratio is $10\frac{1}{2}$ to 1, or a 12-tooth pinion to a 126-tooth gear on the fly wheel. The starting motor will crank the engine at a speed of 150 to 200 revolutions per minute. This automatic drive is shown at Diagram 100.

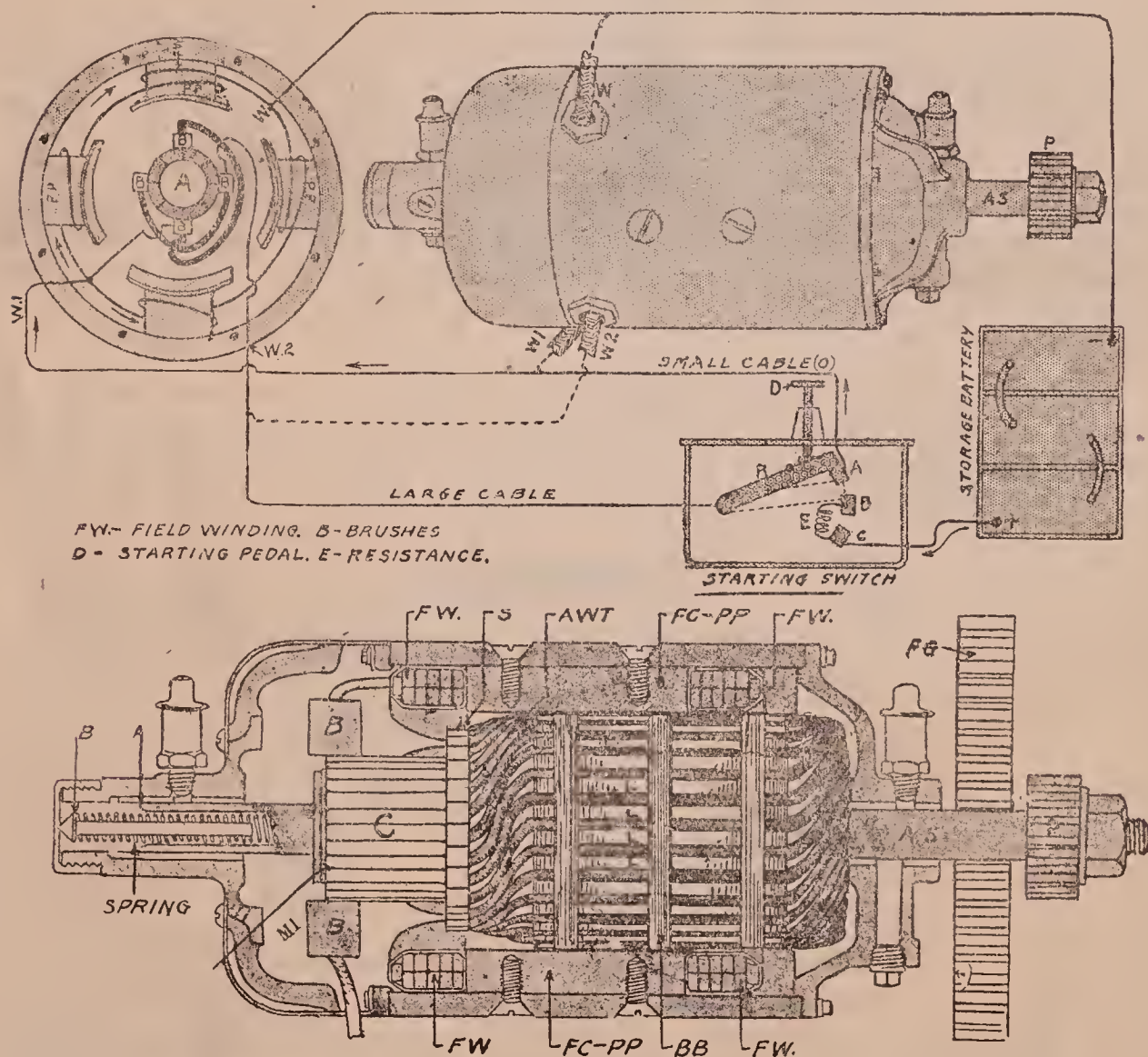


Diag. # 100 The Bendix Automatic Gear Shifting Pinion

No arrangement or levers to slide the pinion into mesh, nor any overrunning clutches are required. It is only necessary to operate the switch of the motor, or press a switch button, and this can be done at the wrong time, when the engine is already running,

without damage. The parts are few and simple. The armature shaft has a screwed extension with an outer bearing, B, and carries the pinion, P. The weight is solidly attached to the pinion and the latter is loose enough on the shaft to always occupy the position shown at diagram 100. With the weight underneath when the shaft is idle, the leading screw is triple thread. On starting the motor the inertia of the weight, W, causes it and the pinion to be carried quickly along the shaft into mesh with the teeth on the fly wheel, where it remains performing the operation of cranking until the engine commences to fire. When the direction of the drive is reversed coming from the wheel to the pinion throws out the pinion. The spring, S, is simply to ease the shock of starting by permitting a side play between the motor shaft and the screwed extension. The teeth on both fly wheel and pinion are beveled on the entering side for easy engagements.

The Electrical Automatic Gear Shift.—Diagram 101 illustrates the construction of the motor. The armature can be shifted endwise in its bearings parallel to its axis. In the normal or nonoperating position, the armature is held out of its electrical center, or in other words, out of line with the pole shoes by means of a spiral spring, as shown in figure 2, diagram 101 at the bottom, in the commutator end of the armature shaft; therefore, when in the normal position the pinion on drive shaft of the starting motor



Diag. 101 The Electrical Automatic Gear Shift

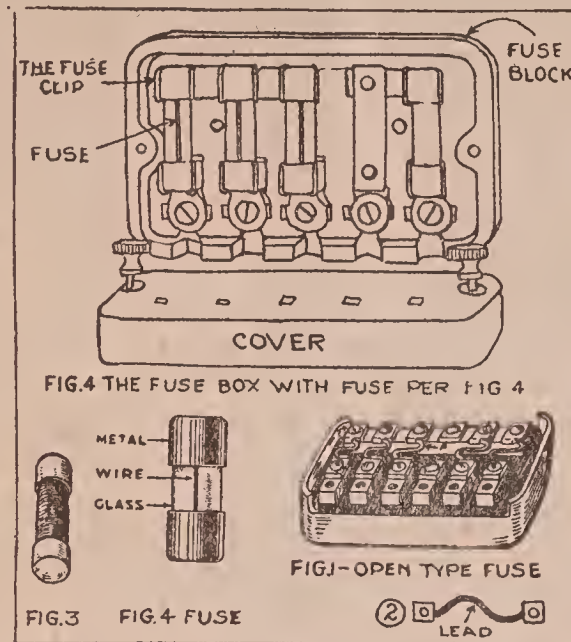
is out of mesh with the gear on the fly wheel of the engine. The motor is regularly provided with three terminals (W, W1, and W2) two of which are heavy, or of larger diameter than the others. The two heavier terminals are for the main circuit and the single small terminal is for the shunt circuit.

Principle of Operation.—During the first part of the downward movement of the switch pedal, D, an electric current is established which causes the current from the storage battery to pass through the switch shunt, E. The amount of current that can flow is limited by the resistance E of the circuit, but of the current which passes through the switch shunt a small portion is allowed to flow through the motor armature, while the greater portion flows through the motor field coils, forming there a strong electromagnet. The result is a powerful attraction between the field coils and the armature, causing the armature to be drawn endwise into the magnetic center of the motor, or in other words, into its working position between the pole shoes. The passing of the small current through the armature causes the armature to rotate slowly, and as the rotary motion occurs simultaneously with the shifting of the armature endwise, the meshing of the motor pinion P with the gear ring on the engine fly wheel F G in figure 2 is accomplished quickly and positively. As the switch pedal, D, reaches its limits of motion at C, the flow of battery current through the switch shunt as well as that through the shunt cables to the field coil is interrupted and a straight series motor in connection is established, allowing the entire current to pass through the motor fields and armature windings and causing the engine to turn over until it starts firing. As soon as the engine starts the starting motor is relieved of its load, and the current passing through it drops rapidly in volume; this being a characteristic of series motors. In consequence the strength of the field magnets is lessened to a point where the spiral spring in the end of the armature shaft figure 2 overcomes the magnetic attraction, holding the armature and returns it to the original or nonoperating position. It is this action that automatically and positively throws the armature shaft pinion out of mesh with the fly wheel ring gear. Thereafter until the starting switch is released and current which continues to pass through the armature will merely cause the latter to revolve freely, but without meshing with the fly wheel, due to the fact that the amount of current utilized when the motor is running free is not sufficient to overcome the tension of the spiral spring.

CHAPTER 34. FUSES.

Fuses are very important, particularly when the ground or single wire system is used. They melt and open the circuit and prevent discharge of battery. There are three types of fuses shown in diagram 102. First, the cartridge type, figure 3; the visible type, figure 4, and the open type, figure 2. The visible type will instantly show when burnt out, whereas in the cartridge type a hole will be blown in the side of the shell. The cartridge and invisible type can be slipped into place by hand: the open type requires a screwdriver. The visible type, shown in figure 4, is a type in general use. The capacity of the fuse in each circuit should be as follows: sidelights, 3 to 5 amperes; headlights, 15 amperes; extra circuits, when provided, 15 amperes. The extra circuits may be used for dome or pillar lights, horn, etc., as desired. In other words, the size of the fuse is determined by the amount of current that is to pass through it. If the fuse is to be placed in the headlight and taillight circuit, and this circuit uses $5\frac{1}{2}$ amperes, a 15 ampere fuse is ample protection.

Multiple Switch Connections for Lighting Circuits.—Example of a multiple switch is shown in diagram 103. To give the reader an idea of the various kinds of connections which may be made by one switch, the contacts have been numbered 1, 2, 3, 4. Note the



Diag. 102 There are three types of fuses, the cartridge type (3) the visible type (4) and the open type (2)

illustration of 103; if 1 and 4 connect, side and taillights are on; if 1 and 2 and 3 connect, then side, tail, and headlights are on; a study of the illustration will make the diagram clear. The switch for turning the lights off and on is usually placed on the dash and should be of the push button type. Instead of using one switch it is advisable to have several push button switches in one bank so that the headlights, sidelights, and taillights will be independent; for instance, it is not always necessary to have the lights

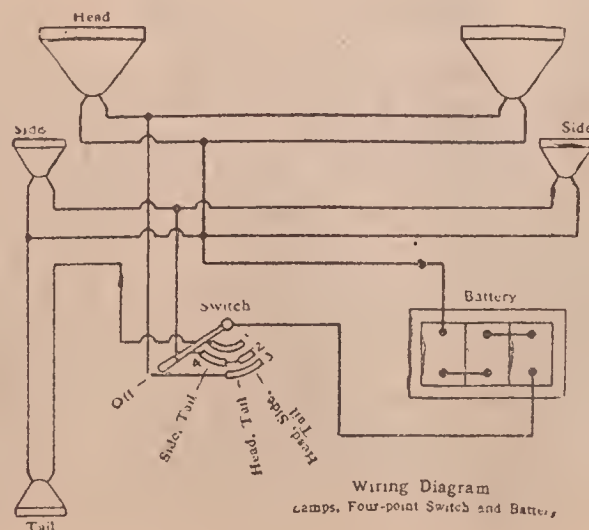
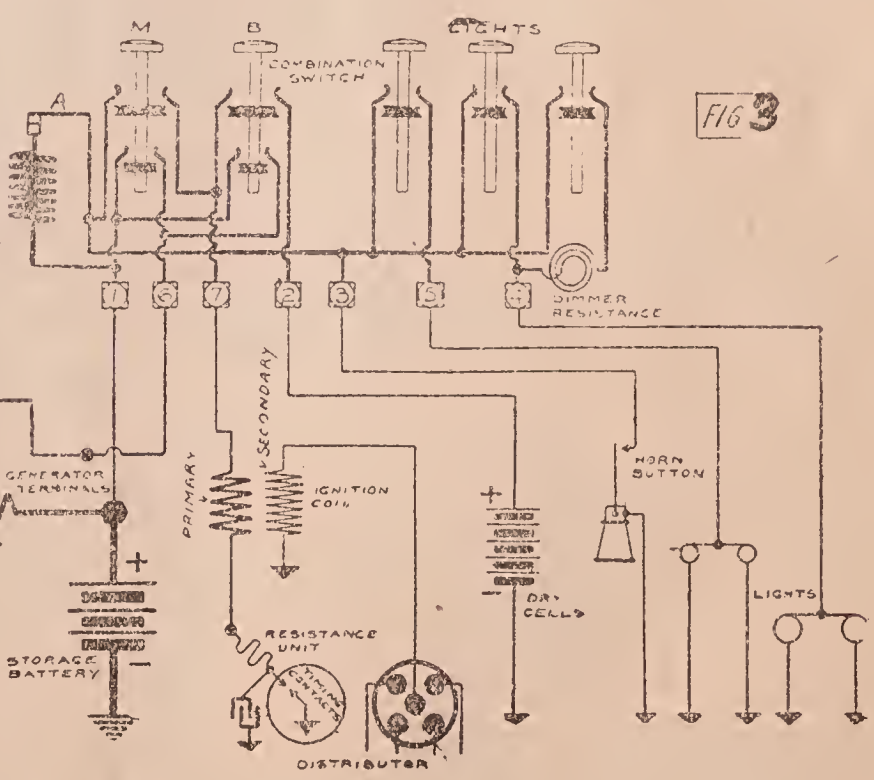
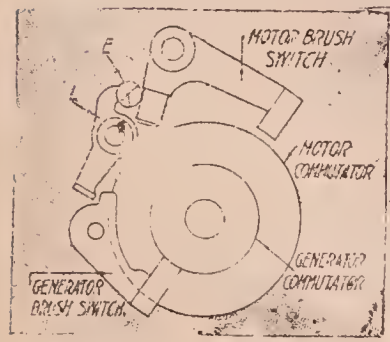
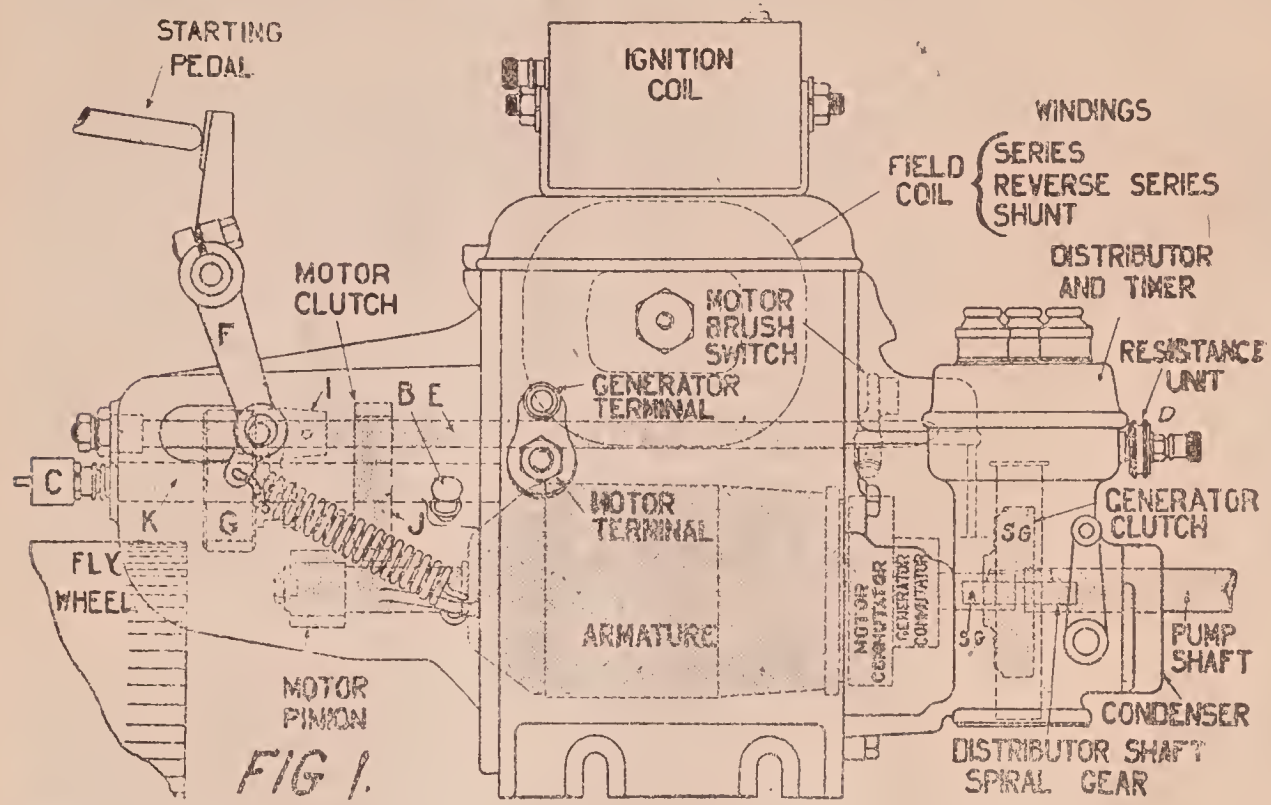


Diagram 103. Multiple switch connections for lighting circuits.

burning when running through well lighted districts; therefore they can be switched off and current saved. In many instances the taillights and dashlights are connected in series; if the taillights should happen to go out, the dashlight will also.



Diag. 104 The Delco single Unit System with Motor Generator and Ignition System combined

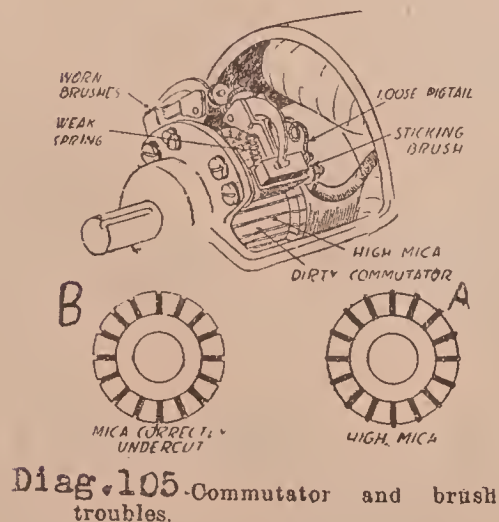
The Delco Electric Motor Generator and Ignition Unit.—In this system we have the motor, generator, ignition coil, distributor, and timer, all compact into one unit which has proven to be very efficient.

The Starting Operation.—Diagram 104 shows the operation of the generator and the motor brush switches, both of which are operated by the pole rod, E; this also operates the starting gear; the complete starting operation is as follows: when either the M or B in diagram 3 buttons on the combination switch is pulled out the circuit between the generator and the storage battery is closed, the current will flow from the storage battery through the generator windings, which cause it to rotate slowly. As the starting pedal is pushed out it operates the pole rod, E, which causes the gear, J, in figure 1 of the motor clutch to mesh with the motor pinion, and this causes the motor clutch to rotate slowly. As the pedal is pushed further out, the gear, G, meshes with the teeth on the face of the fly wheel. As soon as the gears are meshed on the fly wheel the pull rod, E, raises the lower generator brushes of the commutator, as shown in figure 2. When the pull rod, E, has been moved forward enough by the starting pedal to bring the gears fully in mesh, it then allows the motor brushes to drop on the commutator, and completes the cranking circuit. After the engine is started, the pull rod, E, throws gear, G, out of mesh with fly wheel, raises motor brushes, and places the generator brushes on its commutator.

The Generator Clutch.—A clicking sound will be heard during the motoring of the generator. This is caused by the overrunning of the clutch in the forward end of the generator. The purpose of the generator clutch is to allow the armature to revolve at a higher speed than the pump shaft during the cranking operation and permitting the pump shaft to drive the armature when the engine is running on its own power. Spiral teeth are cut on the outer face of this clutch for driving the distributor. This portion of the clutch is connected by an Oldham Coupling to the pump shaft; therefore, its relation to the pump shaft is always the same and does not throw the ignition out of time during the cranking operation.

CHAPTER 35. COMMUTATOR TROUBLES.

The troubles which commutators are subject to, either on motors or generators, are, arcing at the brushes, weak brush holder springs, loose pig tails or connections of the wires to the brushes, sticking brushes, overloading of the generator, and short circuits between the motor and generator windings.



Diag. 105. Commutator and brush troubles.

Mica Protruding Cause of Trouble.—Diagram 105 illustrates the armature, showing the brushes and commutator. At A, figure 105, is shown a commutator with the mica insulation between the segments protruding above the commutator segments; the cause of this mica protruding is the fact that the copper segments are softer than the mica, and naturally wear faster until the mica is so far above the segments the brushes cannot make good contact; therefore arcing occurs and burns and blackens the commutator. Most of the troubles of this nature are due to the use of carbon brushes which are not hard enough to wear the mica down. The commutator, however, where metal brushes are used, the troubles are not so great as they are harder.

To Remedy the Trouble of the Protruding Mica is to cut the mica down between the

segments, say a little over one sixty-fourth of an inch deep between segments. When mica is properly cut, it will have the appearance as per lower illustration at B, 105.

Commutator Noises.—If commutator makes a noise and the trouble is not from the protruding mica the commutator can be cleaned or new brushes fitted, and if necessary smoothed down with sandpaper; use 00 smooth sandpaper; never use emery cloth. To clean the commutator use a piece of cloth dampened with gasoline so as to remove grease and dirt. Never use waste.

Fitting Brushes.—Brushes must always make a good contact with the commutator. They should have sufficient spring tension to press the brushes to the commutator, yet move freely. When fitting new generator brushes, or motor brushes, they do not always fit commutator perfectly; that is, they are not rounded to the commutator surface. This can be remedied by placing the rough side of a strip of sandpaper under the brush. When it is in its brush holder, work the strip back and forth, holding the ends close together. The entire surface of the brush must be treated, otherwise it will be uneven. The pig tails or brush connections must also be kept tightened.

CHAPTER 36. ARMATURE TROUBLES.

Armature windings may be burned out or grounded. When burnt out the trouble may be due to a current overload, or due to improper regulation, a soaked winding, or a steady or prolonged flow from the battery due to failure of circuit breaker contact points to open; a grounded armature winding is due to defective insulation.

CHAPTER 37. LOCATING ARMATURE TROUBLES.

Armature troubles are sometimes found in the attaching leads at the commutator segments. The soldered attachment may be thrown off in revolving. This can be soldered back to the segments by an electrician. Dim lamps, low voltage, the under-charging battery might be the results of armature trouble. One of the armature coils might be short-circuited or burnt out, or a connection might be loose or broken. Any defect in the armature will be indicated by an uneven torque. In the case of the generator, this may be very easily tested by disconnecting the driving mechanism, holding the cut out points closed, and allowing the generator to operate as a motor. If everything is all right, the armature will rotate evenly, and in the same direction as when it operates as a generator. Whether the torque is even or not, may be determined by holding the end of the armature shaft in the hand and noting whether the pull is steady; an uneven pull means that one or more of the coils is not working. It is just like an engine with a missing cylinder. If an armature coil is burned out or there is a broken connection, the armature will invariably stop at a certain point. If this is the case, the commutator segments between the two ends of the coil will also be burned. Sometimes a broken connection occurs at the junction between commutator bar and the coil, in which case the remedy is to resolder.

CHAPTER 38. FIELD WINDING TROUBLES.

A grounded generator or dynamo can be caused by an accumulation of dust worn from the brushes or a defective insulation of the armature or field coil. The field coil may become grounded due to a watersoaked generator or short circuited through burning out, by running the generator with the battery disconnected. You should not, for any reason, run a car if the battery is disconnected from the circuit, unless you have disconnected the chain driving the generator, or the generator itself has been removed; or place dry cells in the place of the storage battery to take the storage battery place. The generator must be kept free from excessive moisture. Ordinary moisture will not affect it, but should not be allowed to become thoroughly wet, such as would be the case if the generator or motor were to become submerged under water. This is likely

to happen while fording a stream. If the generator is wet, it should not be operated until it is thoroughly dried out. This can be done by removing from the car and baking twenty-four hours in an oven whose temperature shall not exceed 220 degrees Fahrenheit. A higher temperature in the baking oven would damage the insulation.

CHAPTER 39. STORAGE BATTERY POINTERS.

1st; Learn to prepare the electrotpe. Use a large earthen crock or lead vessel with burnt seams. One part of chemical pure concentrated sulphuric acid is mixed with several parts of water. The proportion of water varying with the type of cell. Always pour the acid into the water, never the reverse. Use pure water, either distilled or rain water. Allow the electrolight to cool before placing in the cell. The specific gravity should be thirteen hundred. Add distilled water if a higher reading is obtained.

Plate should always be at least one half inch below surface of solution.

2d; Woolen cloth is little affected by acid.

3d; Ammonia immediately applied to a splash of acid on the clothes neutralizes the acid and prevents a hole being burned in the material.

4th; In case a bit of acid splashes into the eye, wash well with warm water and put into the eye a drop of olive oil.

5th; Avoid the use of an open flame in a room where a storage battery is being charged, or in which it has been left for some time, as an explosive mixture of air and hydrogen may be formed.

6th; Storage batteries are rated in ampere hour, this being based on the steady current the battery will discharge. A battery that will discharge at five amperes for eight hours without the voltage falling below 1.75 is rated at a 40-ampere hour battery. This does not mean that 40 amperes would be the output of the battery if discharged in one hour. The ampere hour capacity decreases with the increase in current output.

7th; The current in charging should be kept within the maker's specified limits. One authority advises for rapid charging, covering a period of three hours, fifty per cent, thirty-three per cent, 16 2-3 per cent of the total for each consecutive hour.

8th; The E M F of the charging current at starting the charge should be about 5 per cent higher than the normal E M F of the battery. After a few minutes this voltage may be ten or fifteen per cent higher than the normal battery E M F. However, the battery is kept in the best condition by using a constant charging current, and if necessary to maintain this, the voltage may be raised to 25 per cent higher than the normal battery voltage.

9th; Be sure the positive pole of the charging mains is connected to the positive side of the battery.

10th; To determine the polarity hold the two wires in a glass of acidulated water or electrolight, keeping them at least one half inch apart. Gas bubbles will collect at the negative lead.

11th; A cell is fully charged if with a constant current the voltage and specific gravity do not change in one hour, when the plates decidedly increase the quantity of gas given off. When the specific gravity measures 1300 and the voltage from 2 5-10ths to 2 7-10ths. When the negative plate assumes a light gray color, and the positive plate turns a dark brown.

12th; Never adopt the method of putting a wire across the positive and negative terminals to see if there is any spark. It is almost a dead short circuit, and if the cell be of small capacity of say 30 ampere hour, and the wire number 16 copper, the current may be anything from 30 to 100 amperes for a fraction of time which, when calculated is a very appreciable amount of the total capacity. If only for a second of time duration it is also very detrimental to the cell, assisting the deterioration of the plates or active material thereon.

13th; Lead cells should not be discharged below 1 7-10th volts.

- 14th; Excessive boiling will loosen the active material on the plates.
- 15th; If the cells are hot, while charging, reduce the charging current.
- 16th; If a battery is not in use, give it a short charge once a month.
- 17th; If white sulphate is formed on the plates, it may be reduced by charging at a high rate for a few hours, and overcharging at a low rate for two or three days.
- 18th; Continued sulphating will buckle the plates, as will also too rapid discharging.
- 19th; A cell that has been short circuited should be disconnected from the battery and charged and discharged several times separately.
- 20th; Caring for the battery when not in use; One way to do this is to charge the battery fully, then siphon the electrolight out of the jars to be kept until used again. The plates must then be removed and stored.
- 21st; Never allow the cells to stand in a discharged condition, as it becomes very difficult to get them properly charged if left standing any length of time, unless great care is taken during the succeeding charge.
- 22d; If terminals begin to corrode, clean them off thoroughly and grease them with vaseline.
- 23d; Voltage reading should be taken only when charging or discharging.
- 24th; The temperature of the battery should never exceed 100 degrees Fahrenheit.
- 25th; Use only distilled water to replace loss from evaporation. Add acid only in case electrolight should be splashed out.
- 26th; Each time you charge battery bring the gravity up to maximum or charge until it has remained constant for at least one hour in every cell.
- 27th; When charging the battery put in at least 20 per cent more current (ampere hour) than is taken out, and at every third charge give it a 50 per cent overcharge at the finished rate for the general good of the battery.
- 28th; Voltage readings are only approximate; gravity readings give correct indications.
- 29th; Keep the box containing the battery perfectly dry; if any acid is spilled into the box wipe it off carefully with a piece of waste dipped in ammonia water.
- 30th; When charging at the finished rate, or 24 hour rate, leave the battery on until bubbles begin to rise in the electrolight, then for at least one hour longer.
- 31st; Never add acid or electrolight to the cell except to replace losses from spilling.
- 32d; In cases where the specific gravity will not show any rise during or at the end of its charging, it indicates a short circuit and the cell has not received its charge.
- 33d; In cases where the specific gravity comes up to 1300 at the end of its charge, but falls to a lower figure during a period of idleness, or stands for say twenty-four hours or forty-eight hours, this also indicates a short circuit or else local action or discharge due to contamination of the electrolight by some impurity.
- 34th; The charge must always be given from a direct current circuit, never an alternating unless a rectifier is used, and great care taken to connect the positive wire to the positive terminal of the battery, either directly or through the resistance which is usually necessary. If connected in a reverse direction, very serious injury to battery will result.

CHAPTER 40. SUMMARY OF STARTING TROUBLE.

Starting Motor Cranks the Engine Very Slowly.—Battery almost discharged. Battery sulphated; engine stiff; brushes loose; and poor contact.

Starting Motor Does Not Rotate at All.—Battery may be discharged; starting switch not making good contact; motor brushes may not make contact with commutator; battery terminals may not make good contact.

Starting Motor Rotates But Does Not Crank Engine.—Roller clutch does not work properly; gears not properly meshed; if Benedict's automatic spring broken.

Starting Motor Cranks Engine A Few Revolutions and Then Stops.—Battery weak; almost discharged; loose switch contact; engine stiff.

Starting Motor Cranks Engine but Will Not Pick Up Under Its Own Power.—These symptoms indicate that trouble is not in the starting system, if Benedict's starter gear on thread shaft may be stuck or spring broken.

A Weak Starting Motor is Sometimes Caused by using carbon brushes instead of metallic composition brushes. The metallic composition brushes have three or four times the conductivity that carbon brushes have, and for this reason their replacement by cheap carbon will not allow a sufficient current to pass.

If the Battery is All Right, Proceed to Examine the Connection, beginning with the battery. The current may be shortened, due to electrolight spilled on the top of it; or terminals may be sulphate, in which case enough resistance will be offered to the current to prevent the motor operating properly. Scrape off the sulphate, and wash all the surrounding metal parts in carbonate of soda, or some other convenient alkali, then replace the wire and coat them thoroughly with vaseline to prevent further corrosion. With the starting switch closed beginning with one of the wires running from the battery loosing the various connections in the starting circuit by one, and noting at each point whether there is current flowing by pulling the wire away from the terminal. If there is no current, the motor will not operate at all, and either there is a dead short circuit in some part of the system, or there is a broken wire or connection. The inspection should show where the trouble is.

The Battery Terminals Were Grounded to the Frame.—On single wire systems should be examined to see if connection is O. K. This terminal and its contact surface should be kept clean and drawn very tight if not soldered.

CHAPTER 41. CUT OUT RELAY TROUBLES AND REMEDIES.

The proper care of a modern car's electric lighting and starting system, though apparently a matter of some difficulty, is in reality quite simple, providing a few general instructions are thoroughly memorized. In all cut out relays or controllers found in battery or dynamo wiring, contact points should be kept perfectly clean in order to insure their reliable action. Be sure that the contact points of the cut out actually make contact. The cut out armature may be drawn to the magnetic core, but points may not come really together. Failure of the cut out to operate may be due to several things.

In the first place, a back kick or back firing of the engine will cause the points to close and stay closed, and whenever this happens no time should be lost in separating the points.

This may be done by starting the engine again or by pulling them apart with the hands.

There are several mechanical reasons why the cut out may fail to operate. The points may be too near together or too far apart. The points may be rough or pitted. The points should be smoothed with a fine file and then adjusted. The spring which holds the cut out open may be weak or broken, or the armature may stick, due to worn or tight parts or dirt.

Electrical Defects.—In the operation of the cut out are confined to bad connections or grounds. These troubles are rare and should be quickly evident after an inspection. Failure of the cut out armature to open when the engine is stopped would indicate trouble in the series coil, while failure to close might be caused by a defect in either series or shunt coil. To determine whether the cut out is working properly, the car should be driven on high gear at speed varying from six to fifteen miles per hour, and the speed at which the cut out operates should be noted. The correct speed can usually be found from the maker's instruction book.

Circuits.—See that all circuits between dynamo and battery are intact, and all binding posts and contacts tight.

TROUBLE INDICATIONS AS TOLD BY THE AMMETER.

Ammeter troubles may be divided into two classes; those that manifest themselves when the engine is idle, and those that only show themselves when the engine is running.

Remember that the ammeter should show charge at speeds above eight or ten miles per hour, and that when the engine is at rest and lights turned off, the needle should stand at zero, and not show discharge. It shows discharge when lights are on, and engine idle, or speed less than eight miles per hour; in other words, the battery is then discharging.

If ammeter shows charge instead of discharge, and shows discharge instead of charge, it indicates that the wires connected to the rear of armature should be reversed.

If ammeter indicates zero and the dynamo should be charging battery, it shows that the circuit is open or the dynamo is at fault.

Ammeter does not indicate charge when engine speeds up, but indicates discharge when lights are turned on and engine at rest, dynamo or regulator not working properly. Dynamo brushes do not slide freely in holders.

Ammeter does not indicate charge, engine speeds up and does not indicate discharge when lights are turned on and engine at rest, open or loose connections in the battery circuit, battery terminals loose, dynamo terminals loose, ammeter may be at fault, ammeter indicates discharge, lights turned off and engine at rest, ammeter pointer bent, insulation on wires injured, permitting contact with frame causing short circuit. If, however, it reads discharge, either there is a ground or the ammeter hand is stuck, bent, or out of calibration; that is, it gives an incorrect amperage indication. If the trouble seems to be in the ammeter, it is well to place a test ammeter in the circuit to check the first instrument. If the instrument registers incorrectly, it should be returned to the maker for repair.

Ammeter indicates charge when engine is at rest, ammeter pointer bent, battery connections wrong, but current is flowing.

Ammeter charge indications below normal, dynamo output varies with condition of battery.

Ammeter discharges indications above normal, lamp load excessive, lamp wires in contact with frame.

Ammeter pointer jerks intermittently to discharge. Limits of scale while engine is speeding up, short circuit in system. Fuse blows out repeatedly, lamp wires in contact with frame, lamps defective, short circuited; try new bulb.

Ammeter or indicator registers discharge with all lights off and engine idle, short circuit in wiring from battery to switch, or battery at junction block, ammeter out of adjustment.

If larger than standard bulbs or extra lamps are used, when turned on, discharge indications will be higher; this will cause charge indications to be lower. When car is running at twelve mile per hour or over, the ammeter may even indicate discharge. This is not serious unless there is insufficient day driving or excessive use of lamps at night, thereby permitting battery to discharge.

Ammeter exposes short circuit. If the engine back fires when being shut down and makes one or more revolutions in the reverse direction, the ammeter needle may be found pointing to the extreme left hand side of the scale. This is caused by the circuit breaker contact being half closed by means of a dead short circuit of the battery through the generator. This must be corrected at once by starting the engine.

The ammeter will always indicate if short circuits exist in any part of the wiring except on the battery to the switch buzz bar and in the starting motor circuit.

CHAPTER 42. SHORT CIRCUITS.

The largest number of electric lighting and starting and ignition troubles is caused from short circuits; therefore, it will be well for the reader to familiarize himself with the meaning of the terms used in connection therewith, viz, short circuits, open circuits, and ground circuits.

Short circuits mean that two wires are in metallic connection when they ought not to be. Under such condition the battery will be partially or completely discharged and no lights, or dim lights will be the result. A short circuit may occur at any part in the wiring system, but is usually found at the points of connections or switch terminals and is caused by frayed ends of wires bridging across terminals or short circuits by abrasion, heat of the engine, oil, dampness, or defective insulation. A short circuit may be caused by a wire being in contact with the frame. This is also called a ground.

Bad or Dead Short Circuits.—In this case a cable or wire has probably been cut or jammed or burned so that the insulation has been destroyed and a good firm contact is made with the frame, results—the lights will suddenly appear and go out, but in reality they glow very faintly. A short circuit of this kind will very soon discharge the battery.

Slight Short Circuit.—In this case a short circuited connection is of such high resistance that only a small amount of electricity is lost. Such a circuit is often known as a leak. Results the battery will not hold the charge, and in some cases may become entirely discharged over night. This kind of a short circuit is first noticed when the starter seems weak and the light seems to grow dim at low car speed, and brighten up as the dynamo cuts in.

Indications of a Short Circuit.—First, battery will become exhausted regardless of the charging it receives. Second; battery will discharge over night. Third; lamps when turned on, will burn dimly. Fourth, ammeter pointer may go to the limit of discharge scale. Fifth; starting motor may act sluggish or not at all. Sixth; fuses blow out repeatedly.

A short circuit in any lamp circuit will usually cause a fuse to blow or melt. If this occurs, it is evident that the wires leading from the fuse are in contact with the ground or frame of car, or other metals, or that insulation has been injured and conductor is in contact with other metals, thereby grounding it to frame. The wire must be inspected along its entire length until trouble has been located and corrected. Wires having injured insulation should be wrapped with friction tape to prevent contact with frame or other conductive materials.

Some Causes for Short Circuits: First of all, the ground may be in the battery itself, and may be caused by buckled plates, or an accumulation of sediment. The former trouble is usually the result of charging or discharging the battery at too high a rate which causes the plates to bow, and this creates an excessive pressure on the wood separators between the plates. The vibration of the car soon causes one plate to wear through the separator and come in contact with its neighbor, thus causing an internal short, and the latter is due to neglect to clean the sediment out of the chamber provided for its collections become filled. This would be termed an internal short circuit.

The next place to look for a short circuit is on the top of battery. Spilled acid may cause a partial short circuit. The top of the battery should be wiped clean, treated with a solution of potash, and then the metal parts should be treated with vaseline. If the current is flowing through the external circuit, this fact may be determined by disconnecting one of the battery wires and then touching it for an instant to the terminal it was just removed from. If any current is flowing a spark will be seen. If any considerable amount of electrical energy is being lost, this fact should also be indicated on the ammeter if one is fitted.

As a precaution the starting switch should be examined, as it is possible that it did not release fully the last time it was used, and that some current is short circuiting through it.

Having gone through these preliminaries, the next step is to start from the battery and examine all the circuits, taking the main one first. Disconnect the main feed wires where they enter the junction box, and note whether the ammeter goes back to zero; if it does, there is a ground between this point and the battery.

Put these wires back on, and then disconnect all other wires from the junction box. If current is still flowing the trouble is in the junction box, but if junction box is found O. K., it must be in one of the circuits running from this point. If this is so, then remove wires and test each separately.

Testing for Short Circuit.—First, be sure that a short circuit exists. This test can be made several ways. The ammeter on dash will indicate trouble, but if there is no ammeter on the car, then open all switches, disconnect one terminal of the battery, and strike the connection lightly against the battery terminal in quick succession. If a spark occurs, even though very slight, it indicates a ground or a short circuit, then all is left is to proceed and find the short circuit.

CHAPTER 43. A DIGEST OF LAMP TROUBLE.

Lamps Do Not Light Up.—Examine fuse block or blown fuse. If the fuse is blown, do not replace it immediately, but look over the wiring for an accidental ground, or short circuit. If the fuse in the headlight circuit blows, turn off the headlight switch until the trouble is located and removed. In looking for grounds, abrasion of the insulation on the wire or metallic contact between the wires or between currents carrying parts of the wire devices, and the metal of the car should be looked for. When the trouble has been located and corrected, then replace the blown fuse with others of the same capacity. If fuse is found not blown, look for open circuit, loose contact, battery disconnected or accidentally run down, or burnt out lamps. Examine the cut out switch of the generator to see that it is properly disconnecting the generator circuit. This switch should be in an open position, when the engine is not running and should be in a closed position when the generator is running at any speed over 300 to 450 revolutions per minute.

Lamps in One Circuit Do Not Burn.—This may be caused by the lamps being burnt out. Try another lamp in the same socket. If fuse is found blown, try the same fuse in another circuit. If the fuse is blown do not replace it immediately but look over the wire for accidental ground or short circuit. If the trouble cannot be located immediately, turn off the switch on the damaged circuit until the trouble has been located. If the trouble is in a particular lamp socket, disconnect the attachment plug from this socket, until the trouble can be removed, and see that the removing attachment plug does not dangle in such a way as to make short circuits on the metal of the car.

All Lights Burn Dim.—Usual trouble is, loose or slightly grounded connections, or poor or corroded connections at the battery. More likely the battery simply has not had sufficient charging.

Lamps Too Bright.—Regulator evidently set for a higher voltage. Use lamps of higher voltage.

Lamps Burn Out Often, due either to a poor grade of lamps or lamps used are not of proper voltage.

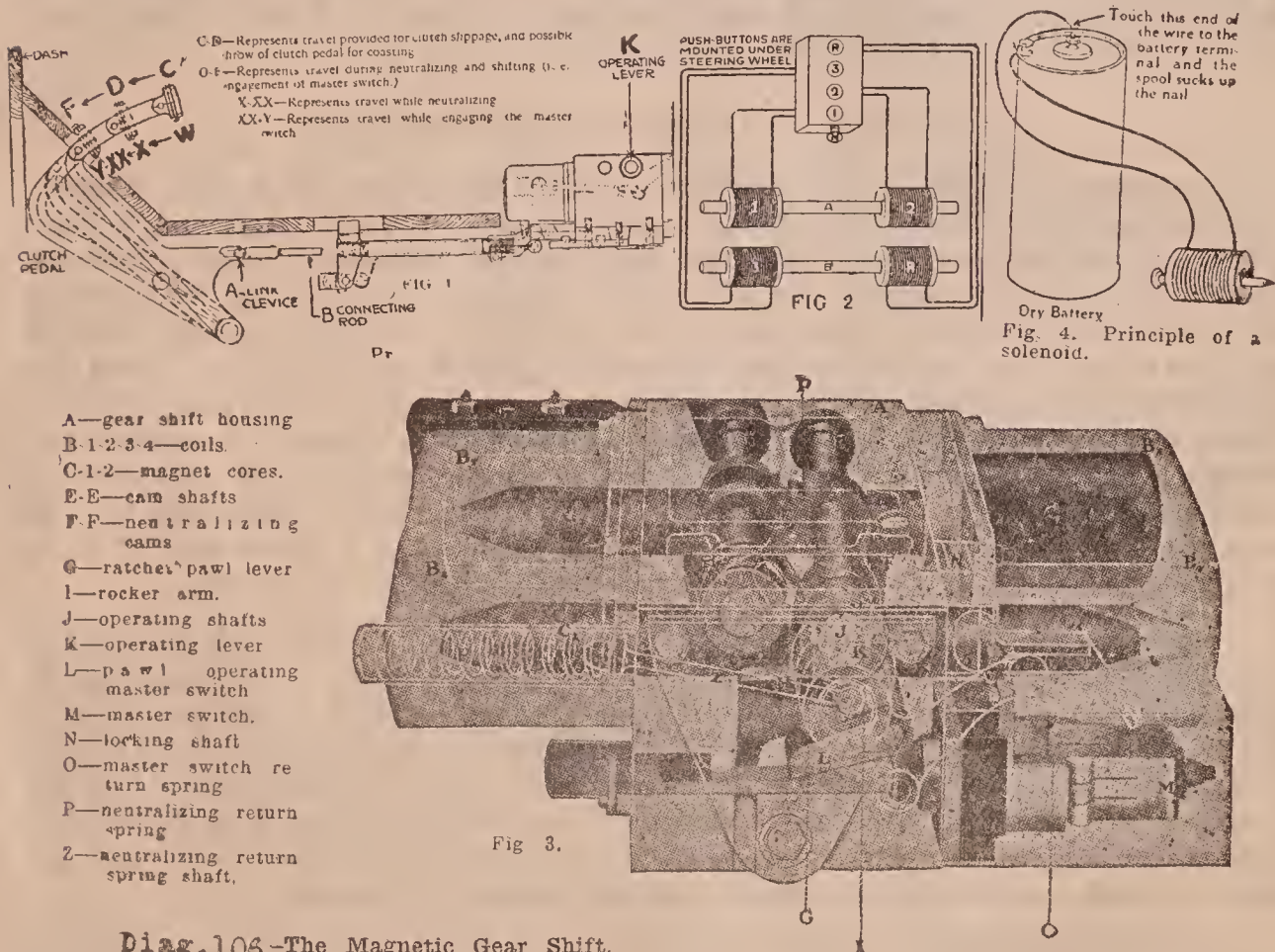
Lamps Flicker and Ammeter Unsteady.—Loose connections in light wires. Loose connections between battery and dynamo. Loose contacts at lamp bulbs, expose wires touching frames intermittently causing short circuits.

Lamps Burn Very Dimly When Starting Pedal is Used.—Battery very weak, almost

discharged, battery injured, probably one or more cells, due to lack of water. Battery terminals not rigidly connected. Lamps become dim when engine stops. This indicates a discharged battery. If possible, have battery charged at once from an outside source. If the lights grow dim when the car is speeded up, the wires are reversed at the dynamo. Lamps will not light but starter cranks engine, lamps burn out, or filaments broken. System short circuited or open circuited at fuse or switch.

Now in order to locate trouble in any kind of an electric system, it must be thoroughly remembered that it is absolutely necessary to always HAVE A COMPLETE CIRCUIT, AND THAT A CURRENT OF ELECTRICITY MUST ALWAYS RETURN TO ITS STARTING POINT; therefore(if its path becomes broken, it absolutely cannot work; and, remember further, THAT A CURRENT OF ELECTRICITY ALWAYS TAKES THE PATH OF LEAST RESISTANCE, and if it can possibly get back home without performing the duty required of it, it will do so; and by keeping these facts constantly in mind when searching for trouble they will assist you greatly in locating it.

CHAPTER 44. THE ELECTRICAL GEAR SHIFT—HOW IT WORKS.



Diag. 106—The Magnetic Gear Shift.

The Principle.—If you press the switch button on as shown in diagram 106, figure 2, you close the circuit of the solenoid number 1, causing the shaft, A, to move to the left. If you press button number 2, you energize solenoid number 2, causing the shaft, A, to move to the right. If you press button number 3, you energize solenoid number 3, causing shaft, B, to move to the left. If you press the button, R, energizing spool, R, you bring the reverse gear into mesh, pressing N, neutral button and throwing out the clutch, neutralizes the gears. Pressing a push button does not energize one of the solenoids; it merely practically closes the circuit to a certain solenoid, but the circuit is not completely closed until you throw the clutch pedal down to the floor board. The

clutch pedal is so arranged that you can throw out the clutch in the usual manner, by partially depressing the pedal, but if you push the pedal to the extreme position you bring the switch, N, figure 3, in contact for an instant and permit the electricity to flow to the particular solenoid which was selected when you pressed one of the push buttons. The push buttons are therefore known as selector switches, because they do not actually close the circuit, but select in advance the circuit that will be energized, when you push the clutch pedal to the extreme position, thereby closing switch M.

A twelve-volt battery is used. It is stated an 80-hour ampere battery will operate the gear shift from 390 to 491 times.

Gear Changes.—First speed. To start forward in first speed, push selector switch button number 1 down until it catches, then push clutch pedal down as far as it will go, and the first speed gear will instantly mesh, allowing the clutch pedal to return gently, the clutch will engage and the car move forward in first speed.

Second speed. Press button number 2 until it catches, and as soon as it is desired to shift the gears from first to second, depress the clutch as before, to its extreme position. This brings the second speed gear into mesh; engage the clutch.

Third speed, press button number 3 until it catches; depress the clutch to its extreme position, allow clutch to return to engagements.

Dropping Back.—In dropping back from one gear to another, the operation is the same, press the button corresponding to the gear wanted, and when it is desired to shift simply push the clutch to the extreme limits and the gears will automatically change.

Selections.—Should button number 2 be depressed and should it then be decided that number 1 is wanted, all that is necessary is to press number 1 button. This automatically kills number 2. Similarly any button that is down is killed by pushing any other button. The gears may be selected in any order desired, for example, 1 to 3, 3 to 1. It is not necessary to press the buttons in numerical order.

Pre-Selections.—Speed changes may be prepared for at any time in advance of the actual shift by pressing the button corresponding to the gear into which it is next desired to fit. When the car is stopped, the gear should always be neutralized before the driver leaves his seat, so that when the motor is again started none of the gears will be in mesh.

Neutralizing.—To throw the gears to neutral, press the end button in figure 2, and then depress the clutch pedal to the limit. The neutral button has no catch and does not remain down when it is depressed. Its function is simply to throw out the other buttons in order to break the electrical connections.

Coasting.—The clutch pedal may be thrown out far enough to free the clutch without neutralizing or shifting the gears. The shift takes place only when the pedal is thrown to the extreme position. This arrangement permits disengaging the clutch so the car can coast.

The Principle of a Solenoid.—This is illustrated very clearly by figure 4, diagram 106, by touching the end of the wire to the battery terminal, which completes a current, around the spool of wire forming the solenoid, creates a magnetic attraction which, if a nail is started in the spool, will be sucked up. This is the principle upon which the magnetic gear shift operates.

CHAPTER 45. THE OWEN MAGNETIC POWER TRANSMISSION SYSTEM.

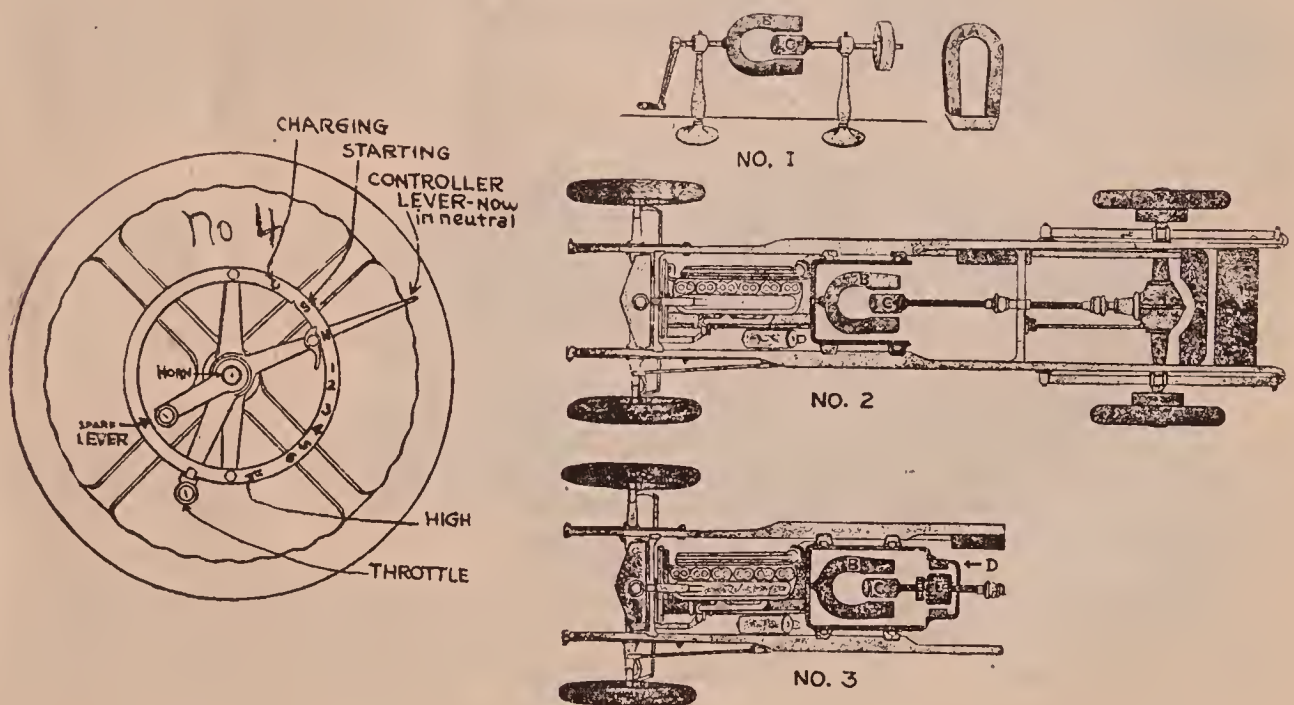
The Elementary Principle.—In diagram 107, figure 1, at A, is illustrated a magnet with keeper, familiar to everyone. B illustrates magnet and pedestal with hand crank to revolve it. C, piece of steel on pedestal placed within magnet. On same line of travel. It will be apparent that as the magnet is revolved by turning the crank it will attract the piece of steel which will revolve quickly.

Illustration number 2 at B is now revolved by a gasoline engine instead of hand cranked, taking the place of the fly wheel, and revolves at engine speed, regulated by the throttle, and to accurately describe it, we will not call B a revolving field, C is now part of propeller shaft, and to accurately describe this we will now call C an armature, and when it is running in high speed, C follows B because it is magnetically locked, but it will be noted that we are driving through an air space or gap, there being no mechanical connections between the rear axles and the gas engine, only magnetism transmitting the torque of the gas engine to the rear axle.

When arriving at a grade which is too steep to climb on high, we would now stall our gas engine unless we applied a form of speed reduction.

CONTROL LEVER POSITION.

Charging—car stationary, engine running, generator charging, starting, and lighting battery, seldom necessary as battery is automatically charged on high speed position when car is in motion.



Diag. 107 The principle of the Magnetic Power Transmission System

Starting.—Current from starting battery operates generator, as a motor for starting engine. When engine has started, bring lever to neutral position as shown in figure 4, diagram 107.

Neutral.—Car stationary, engine running, clutch and generator circuit is open and motor is short circuited on a resistance. Bring lever to first position.

First Position.—Generator producing current for lights, clutching effect, and maximum current for electric motor results. The maximum difference between engine speed and car speed, and produces greater torque or pulling power.

Second Position.—Clutching effect of generator increases and current supply to motor decreases, results, car speed increases.

Third Position.—The clutching effect of generator further increases and transmitting more of the driving power. The motor does correspondingly less work, results in increased car speed.

Fourth Position.—The generator continues to transmit more and more of the driving power. The work of the motor gradually decreases, results, car speed increases.

Fifth Position.—Same general action. The generator carries nearly all the load while motor is practically idle.

High.—On this position the generator clutching effect has increased to nearly locking points, transmitting all the driving power. Motor no longer assists, but operates only as a generator to charge starting and lighting battery.

Illustration number 3, 107, the conventional electric motor, D, as shown gives us reduction needed in the following manner. We now drive through what is in effect a slipping clutch, and it is apparent to us all that if it were possible to use the power that is lost in heat through the friction of the slipping clutch in the old type, gear transmission cars, all the power of the engine would be transmitted to the rear wheels, and there would be no use for a gear box. The magnetic transmission gives us this result, as we now find that C is trying to keep up with B, but as B and C now have ceased to be magnetically locked because we have changed the position of the control lever on the steering wheel, and therefore slipping, the difference in their relative speeds generate electricity which is led to D. Armature, E, being of the same form as C, and on the same propeller shaft, takes the electricity generated by the slip and acts as a power booster on the propeller shaft giving us innumerable speed reduction, wonderful flexibility, and absolute silence at all speeds.

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The man who wins is the average
man;

Not built on any particular plan,
Not blessed with any particular luck;
Just steady and earnest and full of
pluck.

When asked a question he does not
guess,
He knows and answers "no" or "yes."
When set to a task the rest can't do,
He buckles down 'til he puts her
through.

One thing he learns, that a man who
wins,
Finds favor in his employer's eye.
That it pays to know more than one
thing well,
And it doesn't pay all he knows to tell.
So he works and works 'til one fine day
There's a better job with higher pay,
And the men who shirked whenever
they could,
Are led by the man whose work made
good.

For the man who wins is the man who
works,
Who neither trouble nor labor shirks,
Who uses his hands, his head, his eyes,
The man who wins is the man who
tries.

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